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ON

LIFE AND DEATH:

Four Lectures

DELIVERED AT THE ROYAL INSTITUTION OF
GREAT BRITAIN.

BY

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THIS VOLUME

Is Dedicated

TO THE

LADIES AND GENTLEMEN

WHO LISTENED TO THESE LECTURES.

PREFACE.

When I accepted the invitation to give four Lectures on Life *and* Death, I had no intention whatever of subsequently publishing them. They now appear at the request of some who heard them.

I fear I have no better excuse than this to offer for the defects which will be found in the following pages.

Here, too, let me acknowledge, once for all, how largely I have drawn upon the labours of others; because it is impracticable, within the scope of four lectures, to refer to each individual source of information, or even to repeat at any length the facts upon which many most important statements are based. For example, in the first lecture, I have by no means adequately acknowledged the use I have made of the profound philosophy, the masterly labours of Von Baer, nor in the third and elsewhere have I done justice to Dr Carpenter, to whose pen physiology is especially indebted for the establishment of sound principles.

But after all, much, most of what is here set forth, cannot, part by part, be fairly placed to the account of individual minds, for it has, in the course of many years, gradually grown out of the labours of many men.

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LECTURE I.

Scope of the Subject: Purpose of these Lectures—Study of Life—Types of Organisation—Grades of Development—Law of Progress from the General to the Special—Unity of Plan—Sense of the expression, Law of Nature.

I.

Life and death is a vast theme to talk on for four hours only. I need not tell you that this grand subject cannot be fully discussed within a period many times as long. In truth, it would involve nothing less than a comprehensive course of lectures on Physiology; or, as it is sometimes called, Biology; for the solution of this problem is the aim and end of all physiological research. But although disclaiming any vain attempt to do full justice to my text, I shall try, nevertheless, to present to you its main features, and to excite your interest in the consideration of the greatest and most general truths which past labours have revealed. Necessarily foregoing detail, I shall venture to occupy the time allotted to me with the principal conclusions at which philosophers have arrived; perhaps, I should rather say, convictions, seeing that they are held conditionally only, to be confirmed or cancelled, superseded or enlarged, as knowledge advances. This, therefore, will be my purpose: to review the largest and best-established truths,—the general principles of physiology; and thus to occupy, not, I hope, altogether uselessly, the hours during which I shall have the privilege of addressing you.

In the pursuit of my purpose, I shall have but little to communicate of a new or novel nature, for the truths of which I shall have to speak are not the immediate objects of inquiry, but rather generalisations drawn from the accumulation of well-ascertained facts. Our knowledge of life comes less by direct discovery, than as the result of our more perfect acquaintance with subordinate facts, and all tend to elucidate this great problem.

I do not think I can frame any definition of life which would give you nearly so good an idea of it as you already possess. A definition, even if it were sufficiently comprehensive, and at the same time unobjectionable, would altogether fail to picture at all vividly the wonderful phenomena associated with that word.

What can we conceive more complete and intricate than the phenomena of life as they appear in ourselves? How many and various are the actions or functions which minister to it! A process for reducing food to a state of solution—the function of digestion; a process for conveying it when so dissolved into the blood—the function of absorption; another by which, as blood, it is conveyed all over the body to nourish it—the circulation; another for introducing oxygen to combine with the elements of the food and tissues, and at the same time to carry off one of the chief and the most poisonous of the products of that combustion, carbonic acid—the respiration; other organs for excretion and secretion; a marvellous system of organs for motion—the muscles; another, if not more marvellous, at all events more mysterious system—the nervous system, for sensation, for consciousness, for thought and volition—the instrument of mind.

How shall we proceed to investigate and study these, our vital actions—the phenomena of life?

Let us extend our view, and we see the same functions at play in the animals around us. Life in them presents the same features. Their vital actions are like ours. Digestion, absorption, circulation, respiration, motion, and sensation are accomplished in them as in us. And this comparison, this resemblance, applies not to the higher animals only, but may be extended far and wide into the animal kingdom. Nay, it does not stop here. Plants are living beings, and their life presents phenomena comparable with those of our own. However vague and far fetched the comparison between the vital actions of plants and animals may, at first sight, or to superficial observation, seem, the more thoroughly the subject is investigated, the closer does the resemblance appear. The differences which are so obvious are of degree, rather than of kind, and mask the similarity of their essential features. Plants require and take in food and air as we do, and circulate them through the system.

It is true that there is not the slightest evidence that plants possess sensation or the power of voluntary motion; and, therefore, these functions are emphatically termed animal ones, to distinguish them from the rest—digestion, circulation, respiration and so forth—which plants possess in common with animals, and which are therefore termed vegetative. As we shall presently see, however, the line is not thus abruptly drawn in nature. The animal is not so separated from the vegetable kingdom.

Thus, then, in establishing this relation, this community of function, between man and the animals around him, between the animal and vegetable kingdom, a great step onwards has been taken. The life of man is not an isolated problem, defying solution by its intricacy. Well for the student that it is not; for hopeless, indeed, would be the attempt to unravel it, if no light could be cast upon it from around.

But, although we thus meet with essentially the same functions throughout, more or less similar in their details, yet we are at once struck with the different circumstances and conditions under which they are performed. We detect a difference in the character and arrangement of the organs which discharge them. Let us for a few moments consider this.

TYPES OF ORGANISATION.

We can recognise and compare like parts in the structure of the arm of a man, the fore-leg of a quadruped, the paddle of a dolphin, the wing of a bat or of a bird, the fore-leg of a reptile, and the pectoral fin of a fish, because they are constructed upon a common plan or pattern, and contain homologous parts, although in the various cases adapted to distinct and widely different uses.

But although we can compare the wing of a bat or of a bird with the wing of an insect, functionally, inasmuch as they are adapted to analogous uses, we cannot compare them in their structure. They are not constructed out of the same anatomical elements. They do not contain like parts. They are not homologous.

Hence arise types. The animal kingdom—and, by the way, the vegetable kingdom also—is thus separated into groups or sub-kingdoms, all the members of each division being constructed according to a common type, plan, or pattern, and consequently presenting, although under widely different aspects, homologous parts.

But it by no means follows that the same anatomical elements do not occur in creatures constructed according to different types. On the contrary, type refers to the relative position of parts—to the mode in which the organs of the body are united together, although it is often manifested in the conformation of the organs themselves.

Now it will be observed that it is one thing to establish the existence of distinct types or plans of construction—certain unities of composition of parts; but it is another thing to determine what these types are, the number of distinct types according to which the animal kingdom is constructed, and, still further, the particular type to which any given individual belongs. But this is clear: that inasmuch as a type implies a distinct arrangement of parts, it must be, on that very account, opposed more or less to all others. And the very fact that any being is constructed after one type, implies an absence of conformity to any other type.

In animals, and in plants too, structures and organs are often seen in a very imperfectly developed state. Sometimes they appear as mere rudiments or vestiges of parts, which elsewhere occur fully formed. In truth, in no one living being are all the parts and organs fully developed and equally perfected. We may imagine an archetype, but we cannot find one. Even in the highest we see, not complete perfection, but abundant evidence of partial inferiority. We witness the frequency of rudimentary parts and organs.

To many of these no proper functions or intrinsic use can yet be assigned. But their presence is obviously in conformity to the type upon which the animal is constructed. Now this law of conformity to type is generally considered to afford a sufficient explanation of their existence. The idea that they fulfil any further purpose hitherto undiscovered is discarded as superfluous or unnecessary. We are told not to seek for any other explanation of their existence—a morphological one suffices.

But, granting its full force to this view, why should it exclude the idea of a direct purpose, of an intrinsic function for these rudiments or vestiges of structures? Nay, even if we regard them as structures in process of gradual reduction or atrophy, due to long-continued comparative disuse, through successive generations, this cannot be considered as in any wise proving that their present existence is purposeless.

Let me illustrate the argument. A process of bone may exist in conformity to type—it may be a mere rudiment of a structure elsewhere fully developed, or a mere vestige, representing a process of gradual atrophy—and yet it may be useful in affording attachment to muscular or tendinous fibres.

A far better illustration is observed in the number and arrangement of points of ossification in bone. They are in conformity to type, but who can doubt their purpose in each individual case, in relation to the development of bone and its results?

Is it any argument against this idea, to say that we are at present profoundly ignorant of any such direct use for many of these structures? It is one thing that we are unable to discern their function, to discover their use to the individual—even granting that we can give no satisfactory explanation of it—but it is another thing to assume that therefore they are useless.

Moreover, how is it that in such numerous instances there are not in the individual any rudiments or vestiges of parts or organs which we must suppose should exist, if the question were simply one of conformity to type? Why are they often absent, and present only in certain cases, in some of which we can discern their intrinsic use?

It may be very long before we understand so much; nevertheless, I confess, that to me it appears more consonant with the universal scheme—with the complete and perfect adaptation of means to ends everywhere set forth—to believe that even these rudiments or vestiges may—nay, must—have uses of their own; that it is not enough to dismiss them as evidences of conformity to type.

But for some of these structures we can discover an intrinsic use; and is it not fair to assume, even on these grounds, that others have them, although they have hitherto escaped discovery?

To say that nothing exists without its use, may appear a trite observation. Yet we virtually cancel its force, if we admit that morphological laws are sufficient to account for the existence of any part. It appears to me that this is not enough. Here, perhaps, the poet is wiser than the philosopher—

> "Nothing useless is, or low;
> Each thing in its place is best;
> And what seems but idle show,
> Strengthens and supports the rest."

GRADES OF DEVELOPMENT.

But nothing is more remarkable than the infinite diversity of structure and function exhibited by living beings.

In a general survey of the animal kingdom, nothing is more obvious than the various degrees of complexity exhibited in the structures and functions of its different members. Every gradation occurs; from forms of life so simple as to be absolutely structureless under the keenest scrutiny, to others the intricacy of whose structure baffles dissection. And this diversity, be it observed, is altogether independent of type, being exhibited to the full amongst animals which belong to a common type.

The difference in the two cases, between the simplest and the most elaborate or complex being, consists in this—that the functions of the former, such as they are, are performed in common by the general structure; whereas in the latter, each function is performed by a special instrument or structure, and is more or less limited to it. In this way a more complete result is attained.

Now, this difference of complexity which different animals exhibit, is well expressed by the phrase—Grades of Development. The simpler the construction of the whole animal, the lower is the grade of its development: the greater the variety of its organs and functions, the more elaborate the structure, the more complex the phenomena of life, so much the higher is the grade of its development.

It is necessary, however, to distinguish here variety from number of parts. Any structure or organ may be many times repeated, but mere multiplication of similar parts performing the same function does not imply any ascent in the grade of development. But the grade of development is higher, as different organs with special functions are evolved. For example, a centipede does not exhibit a higher grade of development than a man because its limbs are far more numerous. In the great number of its legs we see only the repetition of similar parts adapted to the same function; they do not vary and discharge different functions like the arms and legs of man.

Nor, again, do fishes attain a higher grade of development than mammalia, because their teeth are often three times, or ten times, perhaps fifty times, as numerous. In this vast number, and endless repetition of simple teeth without variation, there is no indication of progress or ascent.

You have probably heard of what is called the principle of division of labour. It simply means this—that where any given result can be produced only through the influence of many different processes, these processes must necessarily be carried on by different agencies. In plainer language, when the work to be done is various, different portions of it must be entrusted to distinct workmen. I say *must* be—that is, if it is to be efficiently performed and the result perfect. And the more various the processes, the more elaborate the result, the further must be carried this subdivision of labour. Now, this great principle seems to be of universal application. It holds good in nature; it holds good in the arts and manufactures. Let us consider the second case first, for it will furnish the more readily-apprehended illustration. Take any ordinary article—say a pin or a needle, as amongst the simplest—and trace its manufacture from the commencement to the conclusion. See through what different processes it passes, and how each of these is entrusted to different workmen. How much more rapidly produced and perfect is the result than if the whole had been carried on by a single labourer! It might all be accomplished by one hand, but at what sacrifice of time and excellence! Take any elaborate instrument—a watch—and the illustration is much more striking. In fact, in proportion to the elaboration of the instrument or machine, so must the number of hands employed in its construction be multiplied.

Milne Edwards happily expounds this principle thus:—In the earliest dawn of society, each man has to minister directly to a number of wants by which he is incessantly assailed, and his energy, however great it may be, hardly suffices to obtain for him a mean and obscure existence. Where civilisation has advanced, each member of the great association executes only a very small portion of a long series of works, which together are necessary to his well-being, and he relies upon the activity of others to obtain in exchange for the superfluous products of his special industry the objects which he wants, and which are prepared for him by the hands of his neighbours. All improves then. Substances become more abundant. A thousand products of luxury are created, and satisfy at once new wants. The culture of the mind is improved, and intelligence advances. At last the genius of a small number develops itself, and is exercised for the profit of the masses. The division of labour, carried to its extreme limit, renders, it is true, more cramped and less brilliant the sphere of activity which occupies the majority of the labourers; but each workman, called on to repeat, without ceasing, the same movements, or to meditate upon the same order of facts, becomes from that alone more able to fulfil his task, and, by the judicious co-ordination of the efforts of all, the value of the total of the products increases with a rapidity which astonishes the imagination.

As in the productions of art, so in the works of nature, we recognise the same great principle of division of labour. To use the expression of Von

Baer, in his masterly exposition of it,—"From the most general forms the less general are developed, and so on, until finally the most special arises;" or,—"A heterogeneous or special structure arises out of one more homogeneous or general, and this by a gradual change."

Thus, as we pass from what we term the lowest to the highest living beings, or from the commencement to the climax of development of any one of them, we trace the gradual evolution of special parts out of the general structure. We have no right to say, from the lowest to the highest; but we may truly say, though with less assumption and complacency, from the simplest to the most complex—from the general to the special. Thus. to take a broad illustration: see in man—in ourselves—to what an extent this principle of division of labour is carried out. Our blood moves, and there is a special instrument or organ, the heart, to propel it. We breathe, and there are special instruments, the lungs, for the purpose. We digest food, and by what a complicated apparatus, with many special parts, is this function performed!

A fluid to dissolve this kind of food; another to dissolve that; a grinding apparatus to reduce it; a muscular apparatus to transmit it, and so on. But now pass to the other extreme of animal life, and look at the common sea-flower or anemone. There is a nutritive fluid—its blood—and this moves; but there is no heart. It breathes; but there are no lungs. It digests food; but the whole apparatus is a simple sac. But you will say, How are all these functions accomplished without organs for the purpose? A pertinent question truly. There are organs; but not special ones. The fluid is moved by the general contraction of the body, which is muscular. Respiration is performed at every part of the surface wherever sea-water can penetrate. Thus, in the common cavity, digestion and respiration simultaneously proceed; and by its contraction the fluid is propelled hither and thither. Nay, in the very simplest forms every portion of the living mass appears to be equally adapted to all the functions which they possess. Every portion of the homogeneous substance of the Amœba appears to discharge in common the functions of digestion, absorption, aëration, contractility, and reproduction. Thus no one part appears to be adapted to a single or special purpose, as in the most complex forms; but each, in common with the rest, assists in the discharge of several functions. But the result of this general arrangement is, if we may dare to say so, comparative imperfection, or, better, comparative incompletion. Each function, in such a case, is less completely performed, although, of course, perfectly adapted to the particular instance.

Thus, then, just as in a primitive state of society several distinct occupations fall to the lot of one man, and are then to a corresponding degree rudely performed, while, as civilisation advances, excellence is attained by division of labour; so in the earliest and simplest forms of life, rudimentary functions are discharged by the general structure, while as we advance onward we recognise division of labour as the principle of progress: special organs gradually evolved for special functions, complexity arising out of simplicity, and the result becoming correspondingly complete.

But note now that just as in society, so in nature, division of labour by no means implies individual independence. No person or organ, however distinct and special may be the duty discharged by him, or the function assigned to it, is independent of those around, or can exist without their help and co-operation, inasmuch as while each contributes his share to the general result, each lacks that which the others supply. In fact, the greater the extent to which division of labour is carried out, the more special the function assigned to each organ; so—and for that very reason—the greater is the degree of their mutual dependence.

Thus, then, in a general survey of the animal kingdom we recognise a vast difference in the grade of development of its various members. Independently of types, we find the utmost diversity in the elaboration and specialisation—or, to use a modern phrase, differentiation—of structures and functions; in a word, in the variety of organs and the consequent complexity of the animal. Nay more, within each type we find great extremes in the grade of development—a fact which at once shews the impossibility of arranging the members of the animal kingdom in a simple, consecutive, and inclusive series ; an idea which has been for some time abandoned, but which existed long enough to produce such theories as those of "arrest of development" and "retrograde metamorphosis."

Therefore, in the study of any living being, these two great questions present themselves : its type of organisation ; its grade of development. They are absolutely distinct, and must be clearly distinguished. This has been long since forcibly laid down by the philosophic Von Baer. He has admirably shewn that neither its type of organisation nor its grade of development alone suffices to characterise any living being ; for under the same type very different grades of development are presented, whilst conversely a like grade of development may be attained under different types. The type and the grade together determine the special form. And this applies not only to the entire plant or animal, but to each system and organ; for it is not more possible to follow any of these through one uninterrupted progression, than it is to arrange either kingdom in a single linear series.

The whole matter may be epitomised thus:—

The PLAN of development—from the general to the special.

The TYPE—the *direction* which development takes.

The GRADE—the *degree* to which development proceeds.

But in the midst of all the vast variety hence ensuing, is there nothing in common, save in the earliest germ? Is there no unity of organisation beyond this? Yes, assuredly. Beneath all complexity and diversity we can discover a fundamental unity of structure—a unity of plan in the means by which the essential portion of the several functions is performed. Whenever you find certain functions discharged at all, you find them discharged everywhere in a similar manner and by structures essentially the same; although, in consequence of the extent to which the essential parts of organs become veiled and obscured in the course of their development and adaptation to special purposes by the introduction of accessory parts, this fundamental unity of plan is more generally obvious in the end than in the means — in the function than in the structure. Not, however, always so. Thus, infinite are the varieties of form and arrangement of the respiratory structure throughout the animal kingdom. It presents all degrees of complexity, from a plain and simple surface to the most elaborate gill or lung—all imaginable forms; each, of course, adapted to the particular circumstances under which aërial or aquatic respiration is accomplished. Yet, amidst all this diversity, the same fundamental plan may be demonstrated to exist throughout. Everywhere there is a permeable membrane, one surface of which is exposed to air or water, while the nutritive fluid is brought into contact with the opposite one. By the extension or inflection of such a membrane, so related to the blood and air, the extent of respiratory surface within a given space is wonderfully multiplied; but this, the essential plan of construction, is never lost.

It may be laid down, that throughout the whole animated creation, the essential characters of the organs and functions which all possess in common are everywhere the same, although they are, under different circumstances, infinitely modified and varied. Thus there is a radical unity in the characters of organs, and in the nature of their functions, wherever they are found. As in chemistry there are compounds innumerable, exhibiting all degrees of complexity, yet in their construction conformable to certain types, and composed of the same essential elements; so, amidst the multitudinous products of types of organisation and grades of development, we recognise organs and functions which in their essential nature are throughout the same.

If time permitted, I might endeavour to develop more at length these grand principles: to trace the functions from their earliest and simplest to their most advanced and elaborate condition, and to endeavour to demonstrate that, while the history of each is one of gradually increasing complexity—while completeness of execution is attained by division of labour—nevertheless, the essential nature of each, and the means by which it is performed, remain throughout the same. For this is of the first and highest importance to the physiologist. If it were not for this identity of structure and function throughout, amidst divers types and grades innumerable, no sound or secure conclusion could be drawn from comparative research. As it is, these endless varieties and modifications are but different aspects and illustrations of the selfsame thing. Thus by comparative research is the best and largest insight gained into human physiology.

I cannot, I need not now, enter further upon this subject—so beautiful, so fascinating—in which absolutely so much, comparatively so little, is known. It is enough for the present to have called your attention to it. I repeat, it is of surpassing importance to us; for upon this basis are constructed the highest and grandest truths of physiology, and some of the most difficult problems have been solved by the evidence which comparative research affords. In fact, any conclusion which will not stand the test of this inquiry is of no value, and falls to the ground.

If anything were wanting to enhance the importance of comparative research, it would be found in the study of Development.

This branch of Physiology, in the nature of its evidence, is closely related to comparative anatomy; and the facts obtained from each confirm and corroborate those derived from the other source. For there is a natural relation to be observed between the tissues and organs of the higher or more complex beings in the course of their development, and the more advanced condition of those of the lower or more simple ones—a relation which has been misinterpreted, misexpressed, and absurdly exaggerated, but which nevertheless exists, and is pregnant with interest and instruction. Let the following illustration suffice :—

In a very early stage of its development, the heart of the chick appears as an elongated sac or contractile tube, connected behind with veins, and in front with an artery. Thus in its general condition it resembles the simplest form of heart met with amongst the invertebrata. Soon the tube becomes bent upon itself, and divided by two constrictions into three compartments, freely communicating. The one in which the veins terminate becomes auricle, the next ventricle, and the third an arterial bulb. Now in its general condition it resembles the heart of a fish. Then the single auricle, ventricle, and arterial bulb each becomes divided into two, so as to form the left and right heart, as it occurs in birds and mammalia.

You may at once understand that the phases of development of an organ or system in the higher animals are not mere repetitions of its perfect state in the lower ones. The relation between the comparative anatomy and the development of an organ or system is simply one of plan—the plan upon or order in which the several parts are evolved; that is to say, in an embryo the more general characters appear earlier than the more special ones.

Beyond this, the only resemblance that can be truly drawn between the embryos of the higher animals in the course of their development and the more advanced conditions of the lower ones, is what may be called a *negative* resemblance. It is due merely to the absence of positive or special characters in either case. In proportion as the special arises out of the general, as the several parts are evolved, the distinction becomes manifest.

With regard to the relation between the higher beings in the course of their development and the more advanced conditions of the lower, perhaps the clearest way of expressing it is this : that at any given stage in the development of the higher, it has attained a grade of development equal to the more or most advanced condition of the lower; but, save in the equality of the grade, the characters are more or less distinct.

Therefore "every embryo of a given animal form, instead of passing through the other forms. rather becomes separated from them. Thus "the history of the development of the individual is the history of its increasing individuality in all respects."

Vain and futile then must be the attempt to study life in any single form of it, or indeed in any one group of forms. Most vain and futile when man himself is selected as an isolated subject of study, seeing that in him all the difficulties of the question reach their climax. Human physiology is but a part, a fraction of general physiology.

Now, to obtain a sound and correct idea of this, or indeed of anything, we must not confine our attention to it alone—in the abstract; but we must consider it in a relative sense—judge of it by comparison and contrast. Whoever would understand the physiology of man must study him in his relation to the world around him. Buffon, in the introduction to his work on Natural History, has well remarked:—"It is only by comparing that we can judge, and our knowledge turns entirely on the relations that things bear to those which resemble them, and to those which differ from these; so, if there were no animals, the nature of man would be far more incomprehensible than it is."

Even if it were desirable, and you attempted at the outset to isolate man as a subject for study, you would find your design before long frustrated by the very nature of the faculties the inquiry evoked. Could you study the blood, for instance, without the questions forcing themselves upon you —Have all living beings this most important fluid? Does it exist universally? Is it always alike?—and if there be differences, what are they? Could any one suppress questions such as these? He were to be pitied who could. Would you not endeavour to obtain answers to such questions, and in this way to throw light, as you inevitably would, on the study of human blood? And whatever the particular subject under consideration. the result would be the same. You could not exclude such reasonable inquiries.

But it is not only in his relation to the animals around him that man must be studied. Our grasp, to be efficient, must be wider than this. He must be regarded not in relation to animals merely, whether high or low, but also in relation to the vegetable kingdom—to plants; even to the simplest forms of life: nay, farther still, in his relation to inanimate bodies—to the inorganic kingdom. Man must be considered as he stands connected with the rest of nature. In truth, a sound knowledge of human physiology implies of necessity an acquaintance with the general characters and mutual relation of animals, plants, and mineral substances. Let me again illustrate my meaning. Take, for example, the subject of food. Suppose we have to consider the food of man, its nature and destination. We see at once that this food consists of various kinds of animal, vegetable, and mineral substances. Now, what are the characters and purposes of each of these principal classes, containing so many and such various compounds? Are they related?—and if so, how, in what manner? Are they all necessary?—and if so, are they all equally necessary? What changes, if any, do they undergo in the system? Now, a correct answer to these and many similar questions, all important ones, involves a certain amount of knowledge at least, concerning the nature of animal and vegetable tissues, and of mineral substances.

The method of studying man by comparison—interpreting him through the simpler forms of life—is not only eminently advantageous, but actually indispensable. Suppose you had to learn algebra over again: would you commence by taking the most complicated equation you could find, and devoting your attention solely and exclusively to it? Suppose that your only object was to learn equations: would you even then dismiss from your consideration the primary rules? Could you learn it thus? You might, possibly, with the aid of a good memory, and under heavy pressure, cram by rote a few formulæ into your head—in the same way, for instance, as a schoolboy is crammed with Euclid—but which would not long remain there, and which would be utterly worthless while they did.

Or to take another subject—music. Would you begin to learn its composition by studying the masterpieces of Beethoven or Mozart? You may have been attracted to the study by such marvellous productions, but it would be a difficult pursuit indeed if you confined your attention to them alone. In fact, you could never even understand such elaborate compositions if you did not view them in relation to simpler and less ambitious works. Your senses, like those of many around you, might be charmed into ecstasy; but you could never, without knowing more, appreciate in all the fulness of their effect the power and labour of those men who could thus from sound evoke such wondrous harmony.

And if this be true and reasonable, shall we deal otherwise with our great equation—man, composed as he is of so many and such vast unknown quantities? Shall we, can we, discard the evidence from below in the study of this consummate product of creative skill, so complex in construction, so harmonious in action? No, we shall never fully appreciate this last, this highest, noblest creation, if we do not listen to the lower notes and simpler strains of nature.

It may be well, in conclusion, to refer to a phrase with which we all are familiar: "Law of Nature"—what is the sense of this?

When we speak of natural *laws*, of laws of growth, laws of development, and so forth, we intend to express nothing more than our idea—so far as we are able to conceive, understand, and interpret it—of the plan of creation; which, because perfect and complete from the beginning, neither requires nor gives evidence of any change. And in truth, it seems that nothing can carry higher our conception of Almighty power and wisdom, than the conviction that all we are permitted to behold, to study, and to enjoy—whether we contemplate the simplicity of Nature's operations in the humblest forms of life, or survey the endless fertility of her resources in the infinitely varied actions of the highest—that all is but the manifestation of one consummate scheme, planned in its full comprehensiveness and perfection from the beginning, needing no alteration, yet nevertheless a constantly-sustaining power. For if the universe owes its creation to His will and power, on that will and power its continued existence must depend. Natural laws are not analogous to human laws. No one can for a moment imagine that the Creator is bound by any law; but in recognising the Divine plan to have been throughout perfect and complete, we understand why it is immutable. The term, Law of Nature, then, is only an expression of the "uniformity observed by the philosopher in the phenomena of the universe." The Law of Nature is the will of God.

LECTURE II.

Essential Features of Life when reduced to its simplest terms—Structure and Function—Nutrition, description of its various forms—Mutual Relation of Organs: Sympathy—Vital Actions; their character, and the changes they undergo at different periods of Life.

II.

Life, after all, constitutes the grand distinction between the organised and inorganic kingdoms. Apart from life, the several lines of demarcation between them, which have been from time to time laid down, have been effaced as science in its progress has either swept away former errors or revealed new truths.

To be sure, the marks of distinction are obvious enough in extreme cases, and in the majority of instances, when applied together, are sufficient to solve any temporary difficulty that may arise; but they are subject to far too many exceptions to make them of much value or importance in those more doubtful cases where they are most required.

Now the features under which life is presented to us are, as we have seen, infinitely varied;

various in form and in expression; varying extremely, too, from absolute simplicity to the most intricate complexity. Witness the several types of organisation, and the innumerable grades of development. Let us then attempt to distinguish the essential, fundamental, or primary features of life—those which are universally exhibited wherever life appears—from those which are accessory to these, or associated with them for special purposes in different cases.

And life, I say, even when presented in its simplest form, constitutes the grand distinction. The difference appears to be infinitely greater between living and dead organic matter, than between dead organic and inorganic substances.

And in order to appreciate this distinction, there is no need to exhibit one's ignorance in any attempt to define life, or to describe it. We are indeed baffled in the study of life, as we are by those subtler traits of structure with which vital phenomena are associated, yet we may recognise and distinguish it by its effects.

I would venture, then, to speak of life as being essentially a state of dynamical equilibrium; as consisting fundamentally and universally in a definite relation between destruction and renewal —in a regulated adjustment between waste and repair, whereby the condition is maintained notwithstanding constant change.

It will be observed that this is no pretence towards a definition of life. It is only an attempt to distinguish life by its essential features, when reduced to its simplest condition, and separated from those elaborate details which belong to it in its more complex forms, from those changes and their effects which are more or less visible in all inanimate bodies.

Life is not a state of resistance. Even now erroneous views too commonly prevail on this point. To say the least, changes are as active during life as after death. The proofs of this are clear and complete. We have only to remember that any man, under ordinary circumstances, in the course of a year, consumes, roughly speaking, something like eight hundred pounds of solid food, about an equal quantity of oxygen, and perhaps fifteen hundred pounds of fluid; that notwithstanding this vast supply, amounting in the aggregate to more than three thousand pounds, his condition during the whole period remains the same, or nearly so; inasmuch as all this matter, after being assimilated into his structure, and forming a part of him, is excreted or cast off in quantity exactly equal to that taken in, but widely different in the forms which it assumes, and in the manner in which the several elements are arranged.

Waste or destruction is a necessary, an inevitable condition of the manifestation of life. It is involved in every vital act. And the power of compensating for this waste or change, the repair or reproduction necessary to the continuance of life, involves that of assimilation—that is, the power of converting foreign matters into the structure of the organism;—in other language, the power of appropriating food.

We cannot conceive life without including both these conditions; destruction and renewal—consumption and supply. For instance, life is not a state of change only as opposed to stability, for this is everywhere simply a question of degree dependent on the conditions to which bodies are exposed. Neither dead organic nor inorganic bodies are immune from change. Again, life is not peculiar as a process of repair only; for it is well known that this may occur in inorganic bodies. If, for example, portions of crystals be broken off, and these, thus damaged, be placed under favourable circumstances in appropriate solutions, they will be repaired. They will not at first uniformly increase, but the edges, or angles, or portions of the surface which have been chipped off will be restored, so that they will recover perfectly their original geometrical form. This, therefore, is repair, or reproduction apart from life.

But in life there is the constant and concurrent operation of these two processes. Both actions are involved in the idea of life, whereby it is distinguished from mere change on the one hand, and from repair on the other. Thus while inorganic and dead organic matter tend to a state of statical equilibrium, during life the equilibrium is the result of compensating actions. It is dynamical.

Change, ceaseless change, then, is the necessary condition of life. The idea of temporary unchangeableness is altogether an illusion. We are never quite the same even for a moment. Life is a flame, a vapour that vanisheth away, are images no less true than trite. A living body, an organism, is a form through which vast quantities of matter are rapidly passing. The human body of an average weight—say of one hundred and forty pounds—is a form through which at least more than a ton of material passes in a year.

I ask you to grasp this all-important and fundamental truth. All this vast amount of material does not merely come into contact with the body and then pass off, but each particle in its turn enters into the composition and structure of the body itself, replacing others which have gone before, to be itself replaced by others which are to come. The body is in no sense as a vessel in which matters are burnt; it is itself the very fuel which is being rapidly consumed.

Why is all this not more obvious? Why do we appear to be, bodily, the same day after day? Whence comes this illusion of temporary stability? Why does the man or woman appear in the same person month after month, nay, year after year, scarcely, if at all, to our perception changed? Simply because in life the demand and the supply, the waste and repair, are so exquisitely adjusted; because in health, perfect and complete renewal waits upon destruction. This is, in a word, nutrition. During life the condition is maintained, and therefore there is no obvious change or loss, as after death. When disintegration and decay alone proceed, the body disappears.

True, this change is much more obvious to superficial view in some structures than in others. Every one knows and sees that the cuticle or epidermis is being continually shed and renewed; so once with our teeth, so many times with the hair—old ones are cast off to be replaced by new ones. All this is patent to casual observation; but change is common to all, an essential feature of every structure. It is not more true that we have a second set of teeth, or from time to time new hair, than that we have often, much oftener, formed, though in a more gradual and subtle manner, new muscles, new nerves, new hearts, and new brains.

If this constant change eludes observation, it is mainly because the process of assimilation is so exact and complete—the restoration, the reproduction is so perfect that no traces of the alteration are left. This perfection of assimilation is illustrated by a fact which might, at first sight, appear to be inconsistent with this constant change. The brain is the organ of the mind—of the mental faculties; amongst others, of the memory. How then are the records of the past preserved if the substance is ever thus rapidly changing? Doubtless every impression made upon the brain affects some portion of its structure, alters it in some subtle and mysterious way; and this impression, this alteration in any particle, is for a while transmitted to its successors by the complete and perfect process of assimilation. I say for a while, for there is a natural tendency in all structures to efface after a time the effects of external influences, and so to revert to their former condition, or to pass through certain changes as they pass through life.

Now let us examine this great subject of nutrition somewhat more closely.

Change, disintegration, destruction is inevitably associated with the discharge of function. Every, even the slightest action, every movement of a finger, every glance of the eye, nay, every sensation, every thought that flashes through the mind, costs structure, uses it, involves its consumption as a necessary condition.

It is a fact which is too often overlooked, that the changes which occur in any structure are always proportional to the activity of its function. The more an organ is used the more it wears, or rather, wastes away. Under all circumstances the waste will be equivalent to the work. From an imperfect apprehension of this fact, results which are utterly incompatible have been ascribed to certain substances used as food or medicine. For example, it has been put forth that alcoholic liquors, such as wine, can increase the activity of the cerebral functions, and yet preserve from corresponding waste the cerebral substance. Now, all we know proclaims the impossibility of separating the one result from the other. If you would save tissue, you must spare its action, for exercise of function involves expenditure of structure, and there is abundant evidence that one is proportioned to the other.

To begin with an illustration from the vegetable kingdom. A seed, if not placed under conditions necessary to its development, may, it is well known, be preserved for years or ages without undergoing any appreciable change, or manifesting any vital phenomena. We know it is not dead, because when placed under favourable circumstances it will become a plant. So the state in which it exists during the interval is aptly termed a state of dormant vitality; and of this I will speak again in the next lecture. But observe now, both function and waste are in abeyance. No vital action—no change of structure. But no sooner does it start into active life than the products of the metamorphosis of its substance appear, and throughout its future career these products are proportioned to the energy of its functions; their amount is a measure of its rate of life.

So in the animal this invariable relation between waste and vital activity appears most strikingly under a somewhat analogous condition. Every one is aware that certain members of the animal kingdom, such as the bat, dormouse, and hedgehog, pass at certain periods of the year into a state which may be fairly termed one of dormant vitality, commonly known as their winter sleep. Now, during this state of hybernation, all the vital functions are reduced to their lowest ebb. They are not absolutely arrested, but their feeble, languid operation can hardly be detected. The heart does not cease to beat, but its pulsations are very slight and slow. So by certain arrangements, feeble and imperfect respiratory movements may be from time to time detected, and so on. Now, in accordance with this extreme reduction of all vital function, the products of waste are reduced to a minimum, and no fresh supply of nourishment in the form of food is required for weeks together. But rouse the animal into an active state, and the contrast is strikingly shewn. A bat, or a hedgehog, or a dormouse may, when in an active state, like any other warm-blooded animal, be drowned in a minute or two, but when hybernating, they will bear submersion for perhaps the greater part of an hour without any ill effect, so very little carbonic acid is thrown out, so very little oxygen is required. When roused to an active state, a fresh supply of food very soon becomes necessary; and if not forthcoming, they must either relapse into a dormant state or die.

Again, at different periods of life this invariable relation may be shewn to prevail. That changes greatly predominate during the active life of youth in comparison with the slower life of old age is proved by the amount of the products of metamorphosis in the two cases, by the relative rate at which the body wastes, and the relative effect of an insufficient supply of food. So again this relation is established in different structures. Compare the rate of waste of nerves and muscles, on the one hand, with that of ligaments and bones on the other, whether this be estimated by the products of their metamorphosis, or by the rapidity with which they waste when the means of repair are withheld. Even in the same structure this fact has been beautifully demonstrated by the researches of Valentin, Matteucci, Helmholtz, and others, who have shewn that carbonic acid and other products of the retrograde metamorphosis of muscle are increased after active contraction.

Thus we can account for the relative vascularity of different tissues, and their more or less immediate dependence on a due supply of healthy blood. For in order that the condition of a structure or organ may be maintained, the amount of tissue consumed must be met by an equivalent supply of new matter. The demand of an organ determines the supply of blood to it. The supply is not a cause but an effect.

It is important to understand the true relation which exists between the nutrition of a part and the flow of blood to it. It is easy to account for the errors which have prevailed on the subject, for there are many facts which, until they are fairly investigated and properly understood, appear to indicate that the relation is reversed. Hunter's well-known experiment may be taken as a remarkable example. He cut out the spur of a cock, and planted it in the comb, where it not only became united to the surrounding parts, but grew into an enormous spiral horn, six inches long.* Now, this great increase of size which it attained in its new locality is a circumstance worthy of all attention. Why did it thus grow? Not merely because there it received an increased afflux of healthy blood. If it were merely because the part to which it was transferred—the comb—abounded more in blood than the leg, whence it had been removed, an increased supply of blood should, we must conceive, affect the nutrition of a part under other circumstances. Yet this does not appear to be the case. In an animal, we know, when the sympathetic nerve is divided in the neck a state of hyperæmia ensues in the whole of that half of the head—the ear, conjunctiva, and nasal membrane become evidently much more vascular than before. This may continue for days, weeks, or months without the least appreciable nutritive change arising therefrom. Notwithstanding their increased vascularity they present, so far as we are able to judge, the same state of nutrition as before. No. To affirm that the supply of blood to a part determines its nutrition is surely to misinterpret the fact. When the spur is transferred to the comb it increases greatly, not merely because the substance is more vascular, but because, uniting with it, it becomes part of a structure where the changes involved in healthy nutrition are more active, energetic. Mere vascularity is not enough. The determining cause is the nature and extent of those changes of which the vascularity of a part is the effect.

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* See Preparation, No. 54, in the Fourth Series of the Museum of the College of Surgeons. No. 52 is a similar specimen.

But it must be observed that just as in the case of the body as a whole, so every part has but a limited duration of life. Each part of the organism has an individual life of its own, and a limited period of existence. In those structures which perish and are renewed molecule by molecule, this natural death and restoration, which is constantly occurring, eludes direct observation; but it is obvious enough in others which perish and are cast off in sensible masses. In the epidermis or epithelium, for example, we are familiar with the fact that the oldest cells, which have reached the surface, are being continually shed and replaced by others from below. Desquamation of the cuticle is a natural process which follows the decay of the worn-out cells. The shedding from time to time of the hair is a more conspicuous example of the same process; so of the teeth, which, in ourselves, in common with all mammalia, are renewed but once, but in fishes repeatedly. As with the cells of the skin, where the process may be most readily studied, so with cells of different kinds elsewhere, as gland cells and blood cells; after attaining maturity they degenerate and die.

Thus during life not only is molecular death constantly occurring, but whole parts, entire structures, are periodically perishing. Nevertheless, the duration of life in each individual particle is modified by the exercise of its function. Those parts which live fastest die soonest. The duration of life is in an inverse ratio to vital activity.

Certain members of the animal kingdom undergo, we know, such strange and striking transformations at particular periods of their life, that we apply to these the term metamorphoses: for examples, insects and batrachia, as frogs and their allies. Now, these great changes, which we call metamorphoses, do not differ in kind from those elsewhere occurring, but are only remarkable in the extent to which they proceed, and the rapidity with which they are accomplished. Observe that they all consist manifestly in the loss of certain parts or organs, and in the acquisition of new ones. Thus, when the caterpillar becomes, through the chrysalis, the perfect insect, the number of its legs is diminished, and it is furnished with wings.

When the tadpole becomes a frog, it loses its tail, and gains legs, and so forth. And these outward and visible changes are associated with corresponding transformations of organs within.

Now, this shedding of old and developing of new parts, from time to time, prevails more or less throughout the whole kingdom of nature, and may be met with in all forms and degrees. If time permitted, I might attempt to describe the strange and startling transformations or metamorphoses echinodermata undergo; how star-fishes and sea-urchins become wonderfully changed at different periods of their life. I might refer to numerous other instances—such as those met with among crustacea—in which the young creature is so unlike the old one, that many curious mistakes have hence arisen; the same individual, at different periods of its life, having been regarded as belonging to distinct genera. But descending from such extreme cases as these, of which the metamorphosis of an insect may be taken as a familiar example, we may pass through various degrees of change met with among batrachia—salamanders, frogs, toads, and their allies—to serpents, in which the entire cuticle is periodically shed—the skin is cast; to birds, where moulting occurs, and mammalia, whose hair is shed and renewed, these structures being cuticular appendages merely; to fishes and others, where the teeth—cuticular structures—are frequently changed throughout the whole of their life; to ourselves, whose teeth, in common with those of all mammalia, are changed only once, but whose epidermis or cuticle is continually being cast off from the surface, and renewed from below. Finally, I might refer to more special instances, as the antlers of the stag.

But it may be observed that the changes to which the term metamorphosis is more properly applied, are distinguished from the rest in this: that there is not a mere repetition of similar parts or structures—as, for example, in the shedding and renewal of the cuticle of the snake—but that the loss of certain structures is associated with the development of others more or less, perhaps altogether, different; that in the insect, some legs disappear, and wings are produced; that in the frog, the tail is lost, and legs acquired. But this again is only a question of degree. Metamorphoses are remarkable in this respect, not because transformation is peculiar to certain animals, but because in them it is so extreme and abrupt.

What living being can be said to present the same invariable characters throughout the whole of its life? Are not changes more or less gradual or abrupt, transformations more or less marked, common to all? Is manhood a mere repetition of childhood? Is old age nothing but a repetition of these? Why is it inevitably otherwise? Truly the transformations are too subtle here to be detected in their progress, but the result is obvious enough. But to pass to more special instances manifest in ourselves. At different periods of life, certain structures pass away, while others are developed. Witness, for example, the earliest blood cells, and those which are subsequently formed. Omitting other more striking illustrations which occur at the earliest periods, we may notice the very different age at which the thymus and thyroid glands respectively attain to maturity. Even the teeth of the first and second set are not alike. Thus, then, metamorphoses, commonly so called, do not differ in kind from the changes elsewhere occurring, but are remarkable only in the extent to which they proceed, and the rapidity with which they are accomplished.

So you see we can draw no abrupt line between these several changes, to the more striking of which the term metamorphosis is applied. These are not exceptional, but only more obvious illustrations of the general law.

Action involves destruction. The exercise of function implies the consumption of structure. Molecular death is an inevitable condition of active life. Repose is necessary to repair. For it is evident, in order that the condition of a structure, or organ, or body may be maintained, this waste must be repaired ; the repair must be equal to the waste—the supply to the demand.

How far these two universal processes of waste and repair may be concurrent—simultaneously going on—is, to some extent, an open question.

The certain fact that active exercise is destructive of tissue, does not preclude the possibility that even during its continuance repair may be, to some extent, proceeding simultaneously with the waste; but it does involve the proposition that during active exercise the amount of waste exceeds that of repair.

Therefore, in order that the waste may be repaired, that the condition may be maintained, there must be periods of comparative inactivity, of more or less complete repose.

As waste, then, necessitates repair, activity, which produces waste, involves repose, the period of repair.

If active exercise could be continued without interruption, it would at length wear out the tissue, destroy it, and the limit to its duration is no doubt connected with the amount of tissue consumed. (The sense of fatigue in organs, as in muscles, may be due to the want of balance between waste and repair.) Exercise, therefore, is followed by repose, the period of renewal; and when this is accomplished, the structure or organ is once again in a condition for active exertion, which must at length, in its turn, be succeeded by repose.

Thus, then, there must be, as the condition of vital action—of life—alternate periods of exercise and repose.

This alternation is illustrated in a general way by sleeping and waking. For sleep, although emphatically rest of the higher nerve centres, is nevertheless a state of general repose. Various circumstances are influential in determining the requisite amount of rest, but of these especially the amount of previous waste, and the rate at which repair is carried on.

Life, then, may be said to present essentially two phases—one of assimilation, and one of function. Assimilation is a source of force; function causes its expenditure.

Now infinite are the modifications under which the alternation of these two processes is presented to our observation.

Certain actions are called rhythmical — that of the heart for the grand example. Now what is the character of this action? It consists in a series of alternate contractions and dilatations of its several chambers, which are produced by equivalent contractions and relaxations of the muscular fibres forming their walls; and these actions are remarkably well-defined and distinct, rapid and regular, and therefore striking. In other words, alternate periods of activity and repose exhibited in an orderly manner. But let us observe elsewhere.

The muscles of respiration obviously exhibit the same condition, though somewhat modified, and subjected to various interruptions and disturbing influences.

In the voluntary muscles, the modification is yet greater. The alternations of activity and repose are less rapid, and far less regular.*

The action of the muscles of organic life is modified in another way. The distinction is less defined and less patent to observation. The action of these muscles, which is termed peristaltic or vermicular, consists in successive and orderly waves of contraction. "Contractions are called peristaltic, or vermicular, which advance through a muscle in a slow and progressive manner. When analysed closely, we shall find that they are only a variety of the active contraction already described. If a number of striped fibres are arranged in a long series, and are contracted in succession, (as in caterpillars,) the resulting movement is vermicular, but in the higher animals, it is only in the hollow, unstriped muscles that this variety of contraction occurs; and the best example of it is in the alimentary canal." But it may be observed in various other parts, as in certain gland ducts.*

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* That is, so far as the muscle, as an organ, is concerned. But if we observe the phenomena of active contraction in individual fibres, we find that "there is an alternate momentary action and repose of every contractile particle."

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* It seems strange that in these cases the need of repose should have been called in question. Yet it has been asserted on high authority that "those functions, which Bichât has described as constituting the system of organic life, may continue to be performed without the need of repose." "The action of the heart, and of the muscles of respiration, ... all these functions are performed during sleep, as well as when we are awake." But

Passing from the muscles to the nervous system, the alternation is most marked in the higher centres, as in the brain, by sleep.

When we pass to what are called the vegetative functions, observation becomes more difficult, and we soon lose our way. Nevertheless, when they appear in their least disguised form, as in plants and the lower animals, we may detect the same alternation; for example, in plants during the day and night.

Therefore, the commonly so-called rhythmical actions are not, in their essential nature, special or peculiar. They are distinguished merely by the more striking manner in which the alternation is presented to our observation. Rhythmical action

surely this is to overlook the nature of rhythmical action. Is not every interval of contraction a period of rest?

No; there is no evidence of any real exception to this law, only apparent ones. True, we say, for example, that the heart is always acting; but we see that its action, strictly speaking, is not continuous, but intermittent. Every part is subjected to alternate intervals of contraction and relaxation, to say nothing of the possibility that only some of the fibres of each part act at one time, while others are passive. The same may be said of the muscles concerned in the act of respiration, and of the plain or unstriped muscles generally.

—periodicity—is only a more obvious form, a more conspicuous example of the essential condition of active life presented everywhere, of exercise which implies waste, and which therefore involves repose necessary to repair.

We all are probably more or less acquainted with the fact that there is a sympathy between different parts and organs of the same body; that, for instance, a local injury, if sufficiently grave, will create constitutional disturbance. A few moments' consideration will reveal the purpose of this. In order that the numerous and distinct functions by which life is represented in the more complex animals may minister to one common end, they all must work in harmony. Therefore, a communication or relation between the several systems of the body must be established, so that the state of any one may influence more or less the condition of the rest. This capability of mutual adaptation which is necessary to their harmonious action, this intercommunication and mutual influence, is well expressed by the familiar word, sympathy. We say that one part sympathises with another, or that the whole body is affected by, or sympathises with, the morbid or unhealthy condition of any part.

Now to what is this universal sympathy due?

The blood is a fluid of most complex composition. Necessarily so; for it is brought into direct relation with food and air on the one hand, and with all the different tissues of the body on the other, in the various processes of nutrition, secretion, excretion. Therefore, it must contain all the substances which the several parts require, receiving these from food and air, and it must receive back again worn-out or used-up matters.

Wonderful, that notwithstanding its complexity and the sources of disturbance to which it is exposed by the continual introduction of raw material on the one hand, and of refuse matters on the other, it can and does maintain the uniformity which is necessary to health. Circulating through the body at any given time, we may say, broadly speaking, there is blood in three stages: blood fit for present use, as it were of to-day; blood which has passed this stage, as it were of yesterday; blood for future use, as it were of to-morrow.

Now we can understand from this, that a right state of the blood and healthy nutrition are mutually dependent: the blood must be right for nutrition to be normal; nutrition must be normal for the blood to be right.

Hence we can understand the aphorism, "Each single part of the body, in respect of its nutrition, stands to the whole body in the relation of a secreted substance." For if any part fails to withdraw from the blood its own proper materials for assimilation, or restores to the blood substances other than those which are the normal result of the changes it undergoes, the blood, we believe, must be thereby, in some measure, and for some time, affected; and hence, as a secondary effect, the nutrition of other parts or organs may, through this altered blood, become modified or disturbed.

Thus, then, distinct and distant structures or organs may sympathise with each other, or the whole may sympathise with the condition of any part, through the medium of the blood. So the nutrition of different organs may be correlative —their evolution and activity concurrent. The growth, development, wasting, or degeneration of one determining, within certain limits, the condition of another.

Hence, as Mr Paget has suggested, may be at least one purpose accomplished by parts apparently the most insignificant—by rudiments or vestiges of structures or organs. By their nutrition they may contribute to the general weal.

So too, as Mr Simon has suggested, this relation between the blood and nutrition may have a pathological application. Certain diseases, apparently local, are generally admitted to have a constitutional origin. Various eruptions, for example, are usually recognised as the effect of a previous abnormal condition of the blood; but Mr Simon extends this view to various morbid growths, such as cancer; such a tumour being in his view a new excretory organ, destined to separate the materials of its nutrition from the blood.

But in all animals, save the simplest, the blood is by no means the only channel of sympathy.

In the more complex animals the nervous system becomes the medium of that immediate and intense sympathy which is so necessary to their well-being. And perhaps the simplest and clearest idea we can obtain of the prime and universal purpose of a nervous system is that of establishing a more direct relation between the various organs of the body. The gradual and subtle sympathies effected through the blood appear to be now not enough. Hence that more marked sympathy familiar to us all, of which the nervous system is the channel.

No one needs to be reminded of illustrations of the effects produced upon distant parts through the nervous system. The influence of various states of the mind upon the bodily functions is thus transmitted. Thus shame or anger reddens the face; thus fear blanches the cheek, and bedews the surface with perspiration.

No additional evidence is wanting to establish the fact that the nervous system stands in a most important relation to nutrition. No one can doubt that the nutrition of a part may be most extensively modified, or perverted, or altogether arrested, by causes operating through the nervous system. But granting all this, however great the influence may be which the nervous system exercises upon the changes which are involved in nutrition, there is really nothing to shew that these are absolutely or directly dependent on it. For instance, pallor and blushing, those simple but striking changes, may be explained by the influence which a certain part of the nervous system exercises upon the calibre of the smaller blood vessels. But perhaps it would be difficult to furnish a better illustration of this influence than that which is presented by the effects of the celebrated experiment of dividing the sympathetic nerve in the neck. The result of this operation on an animal is, that the corresponding half of the head becomes excessively vascular, the vessels are greatly dilated, the ear, the conjunctiva, and the nasal membrane are turgid with blood. Now by transmitting a current of electricity through these parts, all the congestion may be made to disappear: the vessels will contract to their original calibre, and the parts will resume their normal condition. Thus that state of all the minute vessels, which seems normally to depend upon the integrity of the sympathetic system, may be induced by a galvanic current.

But let it be repeated that, notwithstanding the vascular disturbance, the congestion due to the dilatation of the minute vessels which results from the lesion of the sympathetic nerve, the nutrition of the parts concerned gives no evidence of any alteration or modification. This abnormal condition may be maintained for months, and yet no visible effect upon nutrition follows.

Again, while numerous other experiments, such as those of Bernard, tend to shew that certain portions of the nervous system—the sympathetic—are especially related to nutrition and secretion, at the same time these, and others by Brown-Sèquard also go to shew that this relation—which after all appears to be naturally one of control—is only an indirect one, through the influence they exercise upon the calibre of the small vessels, and consequently upon the circulation through an organ. They shew, moreover, that connexion with a nerve centre is by no means an indispensable condition of nutrition and secretion.

But do not let me be understood to contend that every effect which any portion of the nervous system exercises upon nutrition and secretion can be explained by its direct action on the blood vessels. It must be confessed that there are facts of daily observation which cannot be so explained, to say nothing of experiments which shew that increased vascularity of certain glands, and a more copious secretion, follow the excitement of particular nerves. Still in none of these facts, which beautifully demonstrate the influence of the nervous system upon nutrition and secretion, is there any proof of direct dependency.

But that the essential act of nutrition, apart from the conditions which more or less immediately minister to it, such as a due supply of blood—that the change which constitutes nutrition—is not directly dependent on the nervous system, seems to be shewn by the following considerations.

The process of nutrition in all its details is most elaborately and completely carried on in plants, where no trace of a nervous system appears. In the simplest animals, also, all phases of nutrition are accomplished, and yet there is no evidence of any nervous system. Again, in some of our own tissues, as, for instance, in cartilage, no nerves of any kind have been found, and yet in them the same changes proceed; they waste and are repaired; they grow, develop, degenerate—in short, are nourished like other structures. Once more. The first and all-important steps in the development of the embryo are taken before a nervous system exists. In the face of such facts as these, therefore—to say nothing of others drawn from experiment and pathology—the burden of proof rests on those who claim for the nervous system, in its relation to the process of nutrition, a power beyond any kind of influence; who assert that nutrition directly depends on it.*

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* Influence is one thing—dependence another. Yet by a strange confusion the well-known facts which clearly demon-

The great process of nutrition appears in different phases.

As simple maintenance. In this case the waste and the repair, the consumption and supply, are so accurately adjusted that, notwithstanding the most active changes, there is no appreciable alteration of structure. And let it be observed, in healthy nutrition the supply is proportioned, not only to ordinary demands, but, within certain limits, to extraordinary ones. On the one hand, extraordinary activity involves additional waste, and this is associated with equivalent repair; on the other, with deficient exercise there is diminished consumption, and the supply is reduced accordingly. But more than this. When structures or organs are maintained for some time in a state of extraordinary activity, provided only that the exercise be healthy, that the exertion be not excessive, they not merely maintain their condition —the extraordinary loss is not only met by an

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strate the vast influence which the nervous system exercises on nutrition, and this only, have been urged as so many proofs of direct dependence.

equivalent supply—but the increased activity, the additional demand, leads to a supply beyond the waste, so that the structure becomes augmented in bulk or weight, and thus more equal to accomplish the task assigned to it. Take the muscles of the arms of a blacksmith, or of the legs of an opera-dancer, or of the limbs generally of an acrobat, as examples of this. With this increase in quantity is often associated an improvement in the quality of a structure. Thus such enlarged muscles are often of a more ruddy colour than others, and obviously firmer.

The pathologist is familiar with still more striking illustrations of the same fact. Let one suffice. The heart accomplishes its purpose of circulating the blood by the contraction of the muscular walls of its several chambers, certain valves or floodgates being interposed to regulate the direction in which the blood passes. Now when these valves are damaged so as to become inefficient, the blood may either be obstructed in its progress, or allowed to regurgitate. In either case a difficulty arises, which, in order that the circulation may be maintained, must be overcome. To do this the heart is called upon to make unusual efforts—it must work harder than before. In most cases it does so, and thus in time grows larger and heavier—becomes hypertrophied. In such a case the enlargement is not a disease, but, on the contrary, in itself a conservative change, adapted to meet a difficulty which disease has set up—a most salutary effort of nature to avert the impending catastrophe.

The great cause, therefore, of over-growth is increased exercise, within the limits of health, by whatever means that may be called forth.

On the other hand, deficient exercise, want of use, leads to wasting, to atrophy, to loss of bulk and weight, and often to corresponding impairment of quality. Look at the muscles of a person accustomed to sedentary pursuits, or, for a still more striking illustration, at the muscles of a limb, otherwise healthy, which, from accident or disease of a joint, are debarred from a due amount of exercise; how they gradually yet perceptibly waste away, so that at length, when they are once again set free to work, they prove unequal to the slightest effort. That this is the true interpretation of the fact, has been proved by some admirable experiments of Dr Reid, confirmed by others of Brown-Sèquard. Dr Reid paralysed the muscles of the hind-legs of a frog, by dividing the nerves which supply them. One limb he allowed to remain inactive, while the other he frequently exercised by galvanising the lower end of the divided nerve. The muscles of the inactive limb wasted and degenerated. Those which were exercised retained their normal weight and texture. The cause of wasting and degeneration, then, perhaps the most common, at all events the best understood, and the one most under our control, is want of use—want of exercise, according to the law previously referred to.

Thus therefore, within wide limits, the state of nutrition of an organ is determined by the conditions under which it lives. The supply is regulated by the demand. This, beyond doubt, holds good with all our organs. Just as manual labour or repose affects our muscles and bones, so is the condition of the brain improved by mental work, and impoverished by idleness. Thus the brain of the sluggard will inevitably degenerate, while no one can be aware of what he may accomplish, until by a system of active and sustained exercise he has raised his mental powers to their highest degree of efficiency.

So we are led to recognise and appreciate the great value of education, apart from the knowledge it bestows. It is the means whereby the mental faculties are trained, disciplined, cultivated, so as to enable them to act to the best advantage in any case of real emergency.

But let it be remarked that this adaptation within wide limits, much wider, I believe, than they are usually allowed to be, of power to the need of it—that this adaptation requires time, often a considerable period. This is doubtless the chief cause why the extent of this capability is so inadequately appreciated. Such important changes are necessarily gradual ones.

But it may be that an organ is too suddenly called upon to do some extra work, to work beyond its present power. This, under such circumstances, it can only accomplish by excessive action.

There is no more important subject for inquiry than the relation of action to power in the living body. In health the balance is uniformly maintained, or, at least, the supply is equal to the demand. But if from any cause the power of an organ, on the function of which life immediately depends, be much impaired, this difficulty arises: its function must still be discharged, to an extent, at least, sufficient for the purposes of life; and, therefore, deficiency of power may need to be redeemed by increase of action. But action involves exhaustion, and repose is needed for repair. The greater the effort, therefore, the greater the exhaustion. But, again, decreasing power must be met by increasing action. Thus cause and effect react, each on the other; the relation between power and action becomes more and more reversed; until at length the supply diminishing, and the demand for action and repose alike augmenting, the crisis, with rapidly-increasing pace, is hurried on.

No organ illustrates this so strikingly as the heart, and under no circumstances better than in the reaction which follows a severe shock. An inpression is produced upon the heart whereby its power is for some time impaired. But, that life may last, it must still, to a certain extent, circulate the blood. If it be too feeble to accomplish this necessary task at its ordinary rate of action, the frequency of its beat must be increased. But action is succeeded by corresponding exhaustion; and so, if the supply prove unequal to the demand, follow deficient power and excessive action; the pulse increasing in frequency as it fails in force. In this way collapse may indirectly terminate in death through excessive or exhausting reaction; or, if happily the power be sufficient to restore the equilibrium, in ultimate recovery.

But beyond these various phases of nutrition thus determined by well-known causes, it presents different forms at different periods of life.

As with the whole body so with every organ; from its first formation it proceeds to its maturity, and thence to its death. Thus nutrition is presented in the first instance in the form of growth and development; then for a time as simple maintenance; lastly in the form of wasting and degeneration. Observe the difference between growth and development, and between simple wasting and degeneration. Growth and wasting, which are opposite conditions, refer to quantity only. In growth there is a simple increase of bulk or weight. In wasting there is a simple loss of it. Development and degeneration, which are opposite conditions, refer to quality. In development, there is an improvement in the structure of a part, in degeneration the reverse. Growth and development may be, and often are, concurrent, as in the general progress of an individual or organ from infancy, or its first formation, to its adult condition or state of higher perfection, but they are by no means necessarily so. Organs may simply increase in bulk and weight—in quantity—without yielding any evidence of corresponding improvement of quality; as, for example, bones and muscles. Or development may proceed without concurrent growth, nay, with even great diminution of weight and bulk. Thus, in the case of an organ, in certain stages of the development of striated muscular fibre, while the fibre is obviously improving in quality, rapidly assuming the striæ, and other characters which belong to the adult condition, it as rapidly undergoes a decrease of bulk, so that a fibre with well-formed striæ will measure much less than one far behind it in the stage of its development. Again, in the case of the whole individual, Mr Higginbottom has found that tadpoles in developing into frogs lose two-thirds of their weight.

So with wasting and degeneration. They may be, and often are, as in the decline of life, concurrent, but by no means necessarily so. Either one may proceed without the other. The causes which determine one or other of these changes—wasting or degeneration—are at present obscure. We are more ignorant of the conditions which determine between these than of those which regulate growth and development.

But in life there is a power beyond ordinary nutrition, whether it is presented in the form of simple maintenance, or of growth, or development; a power beyond all this, whereby unusual demands may be supplied, extraordinary losses may be met—the power of repair. We are wont to speak of the wonderful adaptation of means to ends everywhere visible in our structures and functions. We are lost in admiration at the marvellous manner in which the wear and tear of our organs is attended by continual renewal. What must we think then of this power of repair? As if it were not enough that the normal wants of the system should be fully provided for—that natural, daily, hourly, constant losses should be sustained and counterbalanced—there is, as it were in anticipation of mischief, of injury or disease by whatsoever cause produced, a power in reserve by which the loss may be restored or the damage repaired. This power, with which all living beings are forearmed, varies widely in its degree in different cases.

The vast and remarkable difference in the effect of injuries upon the lower or simpler, and the higher or more complete animals, depends upon differences in the grade of development. The less the principle of division of labour is carried out—the less the several functions are separated and limited—the greater the extent, when any part is destroyed or removed, to which its functions can be performed by others. So also the immediate effects or shock of any injury is less felt by the simpler forms of life; for where there is less complexity, less division of labour, there is less need of that elaborate harmony, that intimate sympathy between distinct and distant parts which, in the higher animals, is effected by means of the nervous system; through which system the shock of an injury is transmitted.

But more than this. The capability possessed by any living being of repairing injuries, of restoring lost parts, appears to be in an inverse ratio to its grade of development, or to the extent and nature of the changes which it has passed through. (See First Lecture.)

Thus the simplest forms of life will survive mutilation to any extent. Nay, each fragment, possessing in itself the conditions of life, will become a whole. Thus we may rudely imitate nature by the artificial division of polypes and worms. But as we ascend, the power of reproduction becomes gradually limited to certain parts,—to legs or tails, or other appendages, as in tritons and lizards,—until at last in man the power of reproduction is comparatively insignificant. With few and slight exceptions we no longer witness the reproduction of lost parts; we anticipate only more or less complete repair.

These facts should be borne in mind in drawing conclusions from the results of experiments upon the lower animals in relation to man.

Observe, too, that here also type of organisation must not be confounded with grade of development; for under every type a vast difference is apparent. Neither the animal nor vegetable kingdom, even in regard to the power of restoration or repair, can be represented in a single, consecutive, and inclusive series. It is necessary to bear this in mind, for the general statement is sometimes made, that the reparative power in each species bears an inverse ratio to its position in the scale of animal life. But the reparative power of tritons and salamanders is, beyond comparison, greater than that of insects. Yet it would be generally asserted that the amphibia were higher in the scale, as it is termed, than insects. In type of organisation they are ; in grade of development undoubtedly below them.

This remarkable difference in the repair of injuries is observed, not only between different animals, but also in the same animal in the course of its development, and for the same reason. The capability of reproducing lost parts, or repairing injuries, is in an inverse ratio to the extent and nature of the changes passed through.

For example, Spallanzani found in his experiments upon the tails of tadpoles, and the legs of salamanders, that the rate and degree of reproduction were in an inverse ratio to the age. Among frogs and toads, he says, it is only in the very young that any reproduction occurs. And every one is aware that children recover from and repair injuries much more rapidly and completely than adults. Children, we say, will go through so much; because they have gone through so little. The old, for the most part, can bear but little in addition to what they have already gone through. Surgeons, guided by this, do not hesitate to adopt plans of treatment in children which they would not venture to practise on those advanced in life.

Thus, then, different phases of nutrition belong to different periods of life. The seven ages of man—infancy, childhood, youth, adolescence, manhood, decline, senility—may, for physiological purposes, be reduced to three—growth and development, maturity, decline. These are distinguished by the relative degree of the constructive and destructive changes. In the first, the constructive changes are in excess; in the second, the constructive and destructive changes are balanced; in the third, the destructive changes are in excess. But distinguished also, and in this more, by the relative rate at which these changes simultaneously proceed. In early life changes are most active, and they diminish in rapidity as age advances.

In the same animal or plant in the course of its career, different organs, or systems of organs, may attain their most perfect conditions at different periods of time. An illustration of this, in a general way, is presented by what are called the vegetative and animal functions. The former are in full and complete operation long before the latter. The difference is most marked in those cases where the metamorphoses are most abrupt. Compare, for example, a caterpillar with a butter-fly, or a tadpole with a frog. In such cases, how largely, during the first period of existence, vegetative or organic life predominates over animal life. Almost all their time is spent in eating. What a striking contrast to this does the last period of existence present! How little food comparatively is required; in some moths none at all. But what an exuberance of animal life; what energetic expenditure of muscle and nerve force! Very many other more special illustrations of this might be pointed out. Even in ourselves, compare the very different periods at which the thymus and thyroid glands attain to their maturity ; or, again, for a more familiar example, the organs of the senses and of the intellect. We know very well that the senses are possessed in all their acuteness before the intellectual faculties are fully developed, and the senses fail before the intellectual powers decline.

The natural course of the body and of every organ and structure is, development and growth, maintenance for a certain time in a state of maturity or perfection, decline and death. To be born, to live, and to die, is the epitome of the history, not only of every living being as a whole, but, within this general life, of every particle of which it is constructed. "As the race of leaves, such is that of men."

The fairy rings of our meadows which puzzled and delighted us as children, illustrate simply but forcibly the relation of life and death.

These magic circles of simple vegetable cells are continually spreading in ever-widening curves ;

and this is the result of decay and renewal—of life and death: the cells on the central side dying and disappearing, while simultaneously new cells grow and develop on the opposite one. Thus the loss on the one side is met by reproduction on the other. Old individuals die out, new ones succeed. The race continues and extends.

LECTURE III.

Conditions of Life—Material Agents—Dynamical Agents—Their operation and influence—Vital Force.

III.

Let us now consider the external conditions of vital action.

We have seen that change is an essential condition of vital activity. This change is, broadly speaking, effected by the action of the oxygen of the air upon the several structures of the body; the result of which is that they are consumed. Thus vital action, or the discharge of function, involves the consumption of structure. This consumption, or wearing out, or waste, must be repaired; and the source of the restoration and renewal of our structures is food. Thus then, food, including water and air, are the material agents necessary to life.

The supply of these materials is adapted to the urgency of the want. The act of breathing must not be delayed, and accordingly air is everywhere present. Thirst can be borne for some little time; and water, as a rule, is always within our reach. But we are constructed to support the deprivation of food for a longer period, and this comes not so directly; but it is the lot of all, of animals in some degree, and of man more especially, to secure nourishment by labour. "In the sweat of thy face, shalt thou eat bread." With all men, whether savage or civilised, the prime object of life is to obtain their daily bread.

What is the use of food? This is not so simple a question as at first sight it may appear to be. What are the sources of demand for food? However widely opinions may differ on the relation existing between them, there can be no doubt that food is destined to fulfil these two grand purposes:—

The construction and regeneration of the tissues.

The production of heat.

In considering therefore the destination and uses of food, the quantity and quality required, we have to study—

(1.) Nutrition—the repair of waste—the regeneration of substance.—Now, the independent observations of Chossat, and of Bidder and Schmidt, agree very closely on this subject. The former shew that the animal body, on an average, wastes daily one twenty-fourth of its entire weight. The latter, that it will lose in substance, unless it have one twenty-third of its entire weight in food daily. But let it be observed, that these estimates are only average ones. They are liable to extreme variation, through the influence of numerous and powerful modifying causes. As the principal of these, we may notice—

(a.) The nature and constitution of the animal. —Independently of more obvious causes and conditions which determine the quantity and quality of food required—beyond these, much depends on the constitution of the animal. Much, very much, depends on circumstances to be presently noticed, such as exercise, and the temperature to which the body is exposed; but, apart from these, waste and repair proceed far more energetically in some classes than in others.

There are limits, wide though they be, in every case. A reptile could never be on a par with a bird in this respect. Under any circumstance, waste is more rapid, and the dependence on food therefore more immediate, in the bird than in the reptile. And between other classes, or even individuals of the same class, there are differences of the same kind, though varying widely in degree.

(b.) The size of the animal influences its rate of waste.—The proportion of daily waste to the weight of the body appears to increase in an inverse ratio to the size. Thus, from the researches of Frerichs, Lehmann, Bidder, Schmidt, Boussingault, Valentin, and others, the daily waste of albuminous compounds, relatively to the whole body, may be estimated, Brinton says, as follows: in the rabbit, $\frac{1}{140}$th; cat, $\frac{1}{170}$th; dog, $\frac{1}{330}$th; horse, $\frac{1}{700}$th. Therefore the proportion of plastic food required must vary accordingly. This fact deserves especial notice in regard to the relation, to be presently alluded to, which exists between the size of an animal and its loss of heat.

(c.) The period of life has vast influence on the roportion of food consumed.—The young reuire a much larger amount than the old. This ncreased demand in the early periods of life is lue to more than one cause. Being smaller then, he animal is probably on that account alone ubjected to a greater waste of substance. Then, s a growing animal, there must be a surplus of ncome over expenditure. But far beyond these, he great cause is, that in the earlier periods of ife changes are more active—vital processes are nore energetically carried on. Growth and deelopment, which are phases of nutrition, demand, f course, an extra and equivalent amount of ood ; but the addition thus required is, under ny circumstances, comparatively a very small ne. It is true, that at the time when growth nd development are proceeding most actively, he demand for food is greatest ; but there can be o doubt that by far the largest portion of it is onsumed in repairing the waste, which is then ost energetic, and that but a very trivial fraction f the whole is employed in augmenting the weight and bulk of the body. For growth and development, even when most rapidly progressing, are but slow and gradual processes, when compared with the amount of food which is daily consumed.

(d.) But we shall easily understand that, beyond the circumstances just enumerated, which influence the proportion of food required, there is one most influential, and which applies to the same animal at any given period of life. The amount of food which any animal at any time consumes is largely influenced by rest or activity. It is well known that, in the case either of animals or ourselves, the quantity and quality of food which will suffice to maintain the condition in a state of comparative repose, will prove inadequate to this purpose under exercise or exertion. The additional force thus involved implies of necessity the consumption of an equivalent amount of structure; which, in order that the original condition may be maintained, must be met by an equivalent increase of plastic food. On the other hand, if an amount of food be assimilated over and above that required for simple maintenance, and this be not consumed by an extra expenditure of force, an increase of substance will result, and the weight will be augmented. Therefore, for the body to maintain its condition, in the case of a working man or animal, an extra and equivalent amount of food will be required, which excess in a state of rest would increase the weight of the body. For—

All function depends on structure, and action involves destruction ; therefore regeneration or renewal is necessary to the maintenance of vital activity.

The sole source of this repair is food ; therefore all function or vital force is dependent on food. Thus food supplies force.

A given quantity of food of the proper quality can form only an equivalent amount of structure, which can produce only a corresponding amount of function. Therefore, food and force are invariably related as cause and effect ; therefore, given a certain quantity of food, and an equivalent amount of work can be performed.

Ignorance of this has led to miserable mistakes in feeding cattle, and in the construction of diet scales for men, under different conditions of labour and repose.

(2.) Temperature.—Food is the source of heat. Heat is evolved by the combination of the elements of the food, and of the tissues, which are derived from it, with oxygen. All food therefore, sooner or later, by combining with oxygen, evolves heat, some portion more directly, after passing into blood; some less directly, only after having formed tissue. The quantity, and still more the quality, (see further on,) of food required is therefore, in great measure, determined by the amount of heat which must be evolved. And this is influenced principally by—

(a.) The nature of the animal.—Every one knows that there is a wide difference between various classes of the animal kingdom, in the amount of heat which they are able to generate, and the temperature they maintain. We speak familiarly of warm and cold blooded animals; and these terms, although insufficient and erroneous, refer to a most important distinction. Those members of the animal kingdom which are termed warm-blooded, such as birds and mammalia, have the power of maintaining an almost uniform temperature in the midst of extreme fluctuations around them, and this by virtue of their great capability of generating heat; whereas, those members of the animal kingdom which are less aptly termed cold-blooded, such as fishes and reptiles, have comparatively little power of maintaining an independent temperature. Within certain wide limits their temperature varies more or less with that of the surrounding medium. Thus the two classes, between which, however, no abrupt line of demarcation can be drawn, are distinguished by their relative power of resisting changes of temperature. They are also distinguished by their relative power of endurance; for warm-blooded animals appear to be deficient in power of endurance, as cold-blooded ones are in power of resistance. If by any extreme means the temperature of the body of a warm-blooded animal be raised or depressed only a few degrees, a fatal result will be, before very long, produced. Thus, while the one class can resist much but endure little, the other class can endure much but resist little. The powers of resistance and endurance are most variable, but ever, it would seem, inversely proportionate. So we can at once understand what great difference there must be in the amount of heat-producing food which is consumed under these different circumstances ; how much it must be affected by the nature of the animal.

(b.) Size has an important influence upon the relation which the amount of heat generated must bear to the temperature which is maintained. As a general rule, the smaller the size, the larger is the surface which is exposed in proportion to the bulk of the body, and hence, the larger the proportion of the amount of heat produced which thereby escapes. Thus, the smallest of the warm-blooded animals, such as mice and singing-birds, consume, in proportion to their bulk and weight, many times as much food as the larger ones, such as horses and ourselves.

(c.) The external temperature — as season and climate—has a large influence upon the quantity and quality of the food consumed. It is obvious that, in order to maintain a tolerably uniform temperature, more heat must be generated in cold than in warm weather. Hence more heat-producing food must be consumed. A careful study of the diet in different latitudes, when all the circumstances of each case are fairly taken into consideration, fully bears out this significant fact. The apparent exceptions which at present exist, and which have been made far too much of, will probably disappear as our knowledge advances.

Therefore, the question, What is the use of food? what is its destination? is a large one. Food is required for the repair of waste; at times for more than this, for growth and development. Food is required for the evolution of heat. The most economical food is that which most accurately meets these two conditions. Practically speaking, under ordinary circumstances at least, calorifacient food cannot supply tissue. On the other hand, if it be deficient, plastic food must be wastefully expended or consumed in the mere production of heat. The grand point in practice is to adjust the absolute and relative proportions of the different alimentary materials to the conditions required—to have enough of each, and an excess of none.

And again, let me repeat, the quantity and quality of food consumed is largely, very largely, influenced by the amount of work done. The work required to carry on the organic processes of life is subjected to comparatively little fluctuation, and its adjustment is happily beyond our control. But voluntary work, of whatever kind it may be, manual or mental—for the exercise of function involves the consumption of structure, whether muscle or brain—voluntary labour, which varies so extremely, determines the demand for food over and above the amount required to maintain the condition, when there is no external, no extra expenditure of force.

The other material agent necessary to life is atmospheric air. This, every one knows, is principally composed of the two gases, oxygen and nitrogen; for we may set aside the minute quantities of carbonic acid, ammonia, watery vapour, and other substances which are present. Of these two gases, oxygen is the active, nitrogen a passive agent. Nitrogen, so far as we know, takes no active part in respiration. At each inspiration, a certain quantity passes in with the oxygen, and at each expiration a nearly equal quantity is expelled unaltered. The most reliable observations seem to shew that in health, and under normal circumstances, the amount expelled somewhat exceeds that inhaled; but this habitually slight excess appears to be very variable, and is easily reduced, or even converted into a deficiency by trivial disturbing causes, such as a sudden change of diet. Moreover, all the evidence we possess tends to shew that none of the atmospheric nitrogen enters into any form of combination while passing through the system.

But the active agent is oxygen, which is destined to combine with the elements of the food and of the tissues; for the most part, of course, with carbon and hydrogen, producing carbonic acid and water; but also, though to a far less amount, with the comparatively small quantities presented of other substances, such as phosphorus and sulphur. The result of this combination, this oxydation, is that consumption of tissue which is involved in all vital action. By the union with oxygen, those retrograde metamorphoses proceed which lead at length to the elimination of their elements in the various forms in which they appear in the different excretions.

So it seems to be well established that a large proportion of the oxygen inspired enters forthwith into combination with the elements of certain principles of the food, mainly with the elements of non-nitrogenous substances, in the blood itself; so that a considerable proportion of the food is thus directly burnt there, and from thence passes off in the form of carbonic acid and water without ever entering into the construction of tissue. Thus while, at least, by far the largest proportion of nitrogenous matter passes through the form of tissue, a considerable proportion of non-nitrogenous matter is at once burnt in the blood. But all at length, after a longer or shorter route, is oxydised, and so heat is set free. While, then, the primary purpose of nitrogenous material is to repair waste—to renovate tissue—by far the largest amount of heat evolved depends on the oxydation of the hydro-carbons.

Now necessarily avoiding here the discussion of minute details, and remembering how much depends on the operation of numerous modifying or disturbing causes—such as rest or exertion—we may say that, broadly speaking, on an average, between 350 and 400 cubic feet of air pass through the lungs daily, and that out of this about 20 cubic feet of oxygen are absorbed.

An easy expiration expels, we may say, from 15 to 18 cubic inches of air, and this contains, on an average at the ordinary rate of respiration, from 3½ to 4 or 4½ per cent. of carbonic acid. A deep expiration may yield as much as 6 or 8 per cent. Hence as we respire from 15 to 18 times in a minute, about 160 grains of carbon are excreted per hour, or, on an average, about 8 ounces in 24 hours; the quantities varying, however, under extraordinary circumstances, from 7 to 14 ounces. It must be obvious that we cannot so readily determine the quantity of hydrogen which is oxydised, and escapes in the form of watery vapour, for, of course, much of the vapour which is inhaled comes from the water taken in as food. This difficulty has even given rise to doubts in the minds of some, whether any water is formed in the system; but the evidence, direct and indirect, which we possess on this subject, such as the admirable calculations of Vierordt, establish the fact.

Every one believes that the purer the air, the better it is adapted to respiration. Of all impurities, that which is by far the most frequently encountered is carbonic acid, the almost universal product of combustion—the abundant product of every flame, of every breath. Now carefully-conducted experiments satisfactorily shew, that in proportion to the amount of carbonic acid which already exists in the atmosphere, so is the elimination of this poison—for if retained in the blood, it acts as a positive and energetic poison—from the lungs obstructed. Therefore, if we are compelled to respire over and over again the same air, all means of ventilation being prevented, the proportion of carbonic acid exhaled is gradually reduced at each successive respiration. When the amount present in the air reaches a certain level, about 10 or 12 per cent., no more can be thrown off from the lungs. While 5 or 6 per cent. cannot exist without danger to life, half this amount will prove fatal if formed at the expense of the oxygen of the air. The recent elaborate researches of Pettenkofer go to shew, that in order that the carbonic acid in the air should not reach the level which appreciably interferes with its free evolution from the lungs, an adult person should be supplied with at least 60 cubic metres, or more than 2000 cubic feet per hour. This fact of the influence of carbonic acid in the atmosphere upon the function of respiration should be clearly understood.

Since, therefore, everything depends on ventilation, it is impracticable to prescribe the exact amount of breathing room which, as a minimum, should be allowed to each person. But, at any rate, perhaps it should not be less than from 800 to 1200 cubic feet.

There is another question, the opposite of this one, which requires notice: the influence which the proportion of oxygen present in the air has upon respiration. When the proportion is diminished, there is no doubt that the process of respiration is correspondingly impaired; yet, let it be observed, that when the accumulation of carbonic acid is prevented, respiration may still be carried on when the quantity of oxygen is considerably reduced; for an increase of carbonic acid is a far more active evil than a diminished supply of oxygen. But it has been imagined, that by increasing the proportion of oxygen in the air, a larger amount of it might be made available for the purposes of life. The inhalation of oxygen, or of air mixed with it, has been, and is still, from time to time, confidently recommended in cases of impending death from suffocation, whether the result of the simple deprivation of air, or of the inhalation of noxious gases, or as a restorative from the effects of chloroform. Many have not hesitated to attribute striking and beneficial effects to its employment; and in this view it has also been vaunted as a therapeutical agent of immense value in the treatment of pulmonary diseases.

Now very many years ago Sir Humphry Davy investigated this subject. He respired air in which an additional quantity of oxygen was present, and caused mice to do the same. In each case, whatever the proportion of oxygen added, the result was, that less oxygen was consumed, and less carbonic acid produced, than when common air was respired under similar circumstances. The details of these experiments are related in the third volume of his works.

More recently, Regnault and Reiset have declared, as the result of an extensive investigation, that the respiration of animals of different classes in an atmosphere charged with two or three times more oxygen than natural air, does not present any difference from that which occurs in our atmosphere. With the consumption of pure oxygen, the result is the same. The relation between the oxygen contained in the carbonic acid produced, and the total amount of oxygen consumed, does not undergo any sensible change; the proportion of nitrogen exhaled is the same; finally, the animals do not appear to perceive that they are in an atmosphere different from their ordinary atmosphere. And although previous observations made by Lavoisier and Seguin, and by Allen and Pepys, on man, and by Marchand on frogs, seemed to shew that when pure oxygen was breathed, more was absorbed than under normal circumstances; yet they detected little or no augmentation of carbonic acid. Perhaps, also, the well-known facts that when animals are placed in oxygen, they may manifest for a time unusual excitement, that after death the blood is intensely scarlet, and that a similar hue prevails more or less in the tissues—these facts may at first sight seem opposed to the previous conclusion. But be it remembered, it is one thing to have the blood overcharged with oxygen, it is another thing to make this oxygen combine with the elements of the body, to make it available for the purposes of life. We know that the blood always contains a surplus of oxygen, for oxygen exists in large proportion in venous blood; and, so far as we know, in obstructed respiration, the elimination of carbonic acid is a more urgent evil than the assumed deficiency of oxygen.

In some experiments which I have performed in relation to animal heat, I obtained evidence of another kind confirming these conclusions.

I find that when animals are made to respire air mixed with more or less oxygen, their temperature is not increased, but, on the contrary, often diminished one or two degrees or more. In these experiments no error could arise from the accummulation of carbonic acid in the atmosphere, for means were adopted to insure its removal.

If we were in possession of unquestionable facts shewing that the employment of oxygen was more beneficial than the free access of air in the cases alluded to, argument, and even experiment, would be of little avail; but, in the absence of any opposing evidence of a satisfactory character, we must believe that oxygen is not superior, or even equal to pure air. A careful review of recorded cases will, I think, furnish conclusions in strict accordance with the evidence which physiology produces. The statements advanced in favour of oxygen as a remedial agent have failed to convince those most competent to judge of its utility.

The idea of the value of oxygen in therapeutics has doubtless been founded on a misapprehension of the conditions which regulate its consumption. While the experiments referred to confirm the fact, which common sense would assume, that in the atmosphere—the uniformity of the composition of which is a familiar fact—oxygen exists in the best possible proportion and condition for respiration; Regnault and Reiset, in their elaborate essay, conclude—and the conclusion accords with all the evidence we at present possess—that the amount of oxygen consumed depends on internal conditions relating to the blood and the tissues, and is not increased because an unusual quantity is present in the atmosphere.

Thus, the supposed remedy appears to be not only useless, but mischievous. In truth, if useless, it must be mischievous; for in many of the cases in which it has been recommended, moments are unusually precious, and time may be wasted on a worthless proceeding which should be more scientifically, and might be more successfully employed.

Let it be observed, that under normal circumstances there must exist a definite relation between the amount of food which is assimilated and consumed, and the amount of oxygen employed. Thus, to take one striking illustration, we have seen that, in proportion to their bulk, small animals consume many times as much food as large ones. So with oxygen. Careful experiments have shewn that the consumption of oxygen by small birds is proportionally many times as great as by large ones.

The dependence of life on food and air will, of course, be most immediate where the vital functions are most active, and will vary accordingly.

But beyond these material agents—food and air—there are dynamical agents concerned in the production of vital action, of life. These, which have been called vital stimuli, are external forces, such as heat, light, and electricity ; those physical forces whose existence and action we recognise in the phenomena by which we are surrounded, in the endless operations of nature and art.

That all vital action depends on these external agents, dynamical as well as material, may be abundantly shewn.

I have already alluded to the familiar fact that seeds may be preserved for centuries without undergoing any apparent change, but germinating at last when the necessary conditions are supplied —air, moisture, and a certain temperature. Each of these conditions is necessary to active life ; if either be withheld, development is delayed. For example, a seed may be supplied with air and moisture, but development may be arrested by a reduction of temperature. An external force in the form of Heat is essential. Without it all is still: there is no sign of life. In the vegetable kingdom this is most strikingly illustrated in cellular cryptogamic plants, spores, and seeds, but is more or less evident in all plants at any period of their existence, under the influence of considerable variation of temperature. In the animal kingdom it is commonly illustrated in eggs, but many of the adult forms of life may be reduced to a state of absolutely dormant vitality by reduction of temperature. The celebrated observations and experiments on rotifers, snails, slugs, caterpillars, and on fish, frogs, salamanders, and snakes, furnish ample proof of this

This state, which is well termed dormant vitality, is interesting and most instructive. It may be studied in every degree, from its most complete form, where all change is in abeyance, in spores and seeds, and the simplest members of either kingdom, to the phenomena of hybernation, and through this to that of ordinary sleep, where there is but a comparatively slight and transient reduction of vital activity in the highest and most complete members of the animal kingdom. Nor does it appear from any well-authenticated and sufficiently trustworthy facts that these are susceptible of a reduction of vital activity much below that which occurs in profound sleep; for here life so immediately depends on certain external agents that it soon ceases to exist when they are withheld, and under ordinary circumstances decomposition supervenes.

In a state of dormant vitality, then, there is the capacity for, but not the manifestation of life—no vital action. Of the two necessary conditions of active life only one—the organised structure—is present. The other—the operation of external forces—is wanting.

But although this state of dormant vitality is usually induced by the withdrawal of external agents, it does not appear always to depend on this cause. It may be due to some change in the organism itself, which, when normal, generally exhibits a tendency to periodicity. For example, the regular recurrence of sleep and hybernation cannot be altogether explained by the influence of external causes. There is something more than this; some cause operating within. (See the remarks on rhythmical action in previous Lecture.) So too, among insects, the final metamorphosis of some individuals is in certain cases delayed for many months beyond that of others even of the same brood, under circumstances that will not admit of explanation by the influence of any known external cause.

So too, an abnormal state in which the vital functions generally are reduced sometimes to a minimum, it may be even below recovery, can be induced by special and peculiar causes operating within. Such a state supervenes when a person faints.

The relation of heat to vital activity is further shewn in nature everywhere. The influence of the seasons upon plants is an almost universal and ever-recurring illustration. So is it exemplified in the obvious relation which prevails between the flora and temperature of different latitudes from the pole to the equator, or at different altitudes from the level of the sea to the mountain top. The influence of heat may be examined more closely. Its dominion over the rate of life is clearly shewn in the effects of temperature upon cyclosis and the circulation of latex. Any one who has watched the rotation of the contents of the cells of chara, vallisneria, anacharis, or other plants, will know that the rate of movement is determined by heat—that it may be checked or accelerated by varying the temperature.

As in the vegetable, so in the animal kingdom. A definite relation prevails between the fauna and temperature of different regions. Take for example the facts disclosed by Milne Edward's researches upon the geographical distribution of crustacea. These have shewn that as we pass from the polar seas towards the equator they become more abundant and larger; that varieties of form and organisation are more numerous, characteristic, and important, and that there is an increase in the number of species.

Again the influence of heat upon vital activity is most remarkably illustrated in those cases in which changes or metamorphoses are most abrupt, as in the rate of development of the larva from the egg, of the chrysalis, and the evolution of the perfect insect. Every one must know how these changes are accelerated in the silkworm, for instance, by warmth. The influence of heat on the development of tadpoles into perfect frogs has been clearly set forth in Mr Higginbottom's experiments. These have shewn more than the bare fact that the temperature to which they are exposed exerts a vast influence upon the rate of their metamorphosis.

Again the influence of temperature is most marked upon respiration—that is, upon the demand for oxygen and the evolution of carbonic acid, which may be taken as an exponent of the rate of life. In cold-blooded animals, as fishes and batrachia, this demand, within certain limits, varies directly with the temperature: within certain wide limits, for it has been found that when these are passed the relation is reversed. For example, when the temperature of the medium in which a frog is placed is gradually lowered, its respiration declines in a corresponding ratio down to a certain point which seems to be its limit of endurance. As the temperature is still further depressed, the respiration appears gradually to rise; an effort is then made to resist any further reduction.

In warm-blooded animals, on the other hand, which cannot endure internal changes of temperature, as birds and mammalia, the respiration varies inversely as the temperature. They resist changes of temperature, maintaining an equilibrium by generating more heat as more is lost. But in all animals, whether warm or cold blooded, it has been found that the duration of life, of the body generally, and also of individual structures, when deprived of air, is inversely as their temperature. This will be understood when it is borne in mind that the vital activity of any structure or organ varies with its temperature, and that in proportion to its rate of life is it more or less immediately dependent on a due supply of oxygen.

Lastly, let it be observed that some vital processes seem to require more heat than others. Thus, it has been observed, an increased degree of heat is furnished at the period when young bees escape from the egg, and a higher temperature has been detected under similar circumstances in other instances, as in some serpents. So, too, in Mr Higginbottom's experiments first referred to. He found that when tadpoles were not supplied with a sufficient degree of heat to enable them to develop into frogs, they still continued to increase as tadpoles, still growing therefore in a temperature at which they could not develop. And again, when the limbs of young tritons are removed, it depends on the temperature to which they are subsequently exposed whether the member is reproduced, such regeneration not occurring in a temperature below about 60°, Fahr.

The influence of Light is more manifest, and therefore more easily calculated, in plants than in animals; for it is through this force that plants are enabled to discharge their characteristic function of decomposing carbonic acid, and appropriating carbon. This power of assimilation which plants possess requires light; it only proceeds in its presence. The production of colour is the marked effect, and may be regarded as a fair exponent of their vital energy. Thus plants display the most vivid colours under the influence of the brightest light, and become etiolated when deprived of the due influence of that agent. But it is difficult or impracticable, in many cases, to separate or distinguish the operation of light from that of heat. Thus, much light does not always appear to be necessary to colour, for Humboldt and others have discovered plants, highly coloured, growing in places, such as in mines, which, at the best, could only receive very feeble illumination.

Again, to the simple plants, intense light may be excessive. Thus, some of the lower cryptogamia seem to flourish best in northern aspects, avoiding the glare of a southern sky. Fungi especially, as every one knows, flourish best in darkness; but this exception goes to prove the rule. Fungi differ in their mode of nutrition from the vegetable kingdom generally. They do not appear to possess the power of converting inorganic into organic substances ; at least to an extent at all corresponding with that of plants generally, but, like animals, they assimilate organic matter. Germination also is accomplished in darkness, and a similar explanation holds good in this case ; for the embryo, at first, does not assimilate inorganic matter, but subsists for a while on the store of organic matter laid up for it in the seed.

Many beautiful illustrations of the operation of light on vegetable life might be drawn from the influence which it exercises on growth and development, on the direction of leaves, branches, stems, and roots ; in short, on the whole, and every organ of a plant.

The influence of light on the functions of animals is less obvious than on those of plants, and requires more extended and elaborate investigation ; yet we are already in possession of some important facts illustrating its operation. It might have been expected that its effects upon vital action would be most marked in those cases in which certain changes are most abruptly accomplished. Thus, it has been observed that the operation of light has a large influence in determining the rapidity with which the minute entomoscracous crustacea cast their shells. But it is most interesting, in relation to the influence of light upon plants, to find it operating on the production of colour in the animal kingdom. Thus Milne Edwards has noticed its influence upon the colour of the shells of some mollusca. When the animal has lain for some time half concealed under the shelter of a rock or sponge, the part of the shell shut off from light has remained comparatively colourless while the portion exposed has been brilliantly tinted.

Let me here allude to the remarkable phenomena which have been witnessed in the cells of the skin of various animals in connexion with the peculiar changes of colour they from time to time display.

In the skin of such animals, of which the well-known chameleon is the most striking example. are seen scattered in great abundance a vast number of cells, very variable in size and shape in different examples, but all distinguished by their contents, which consist of pigment generally in the form of granules, presenting various colours. The example most familiar to microscopic observers is the stellate, branching cells, more or less filled with pigment, for the most part black, found so abundantly in the skin of the common frog, and which are such conspicuous objects when the transparent web of the foot is examined. Now, it has been known for a long time that the various shades of colour which this animal exhibits under different circumstances are connected with the manner in which the pigment is arranged within the cells, principally with its state of aggregation. Concerning the agency by which the arrangement of the pigment granules, which are suspended in a colourless fluid in the interior of the cells, is altered, opinions differ, but it is unquestionable that the remarkable changes of colour are connected with such alteration. Sometimes all the pigment is accumulated in the centre of the cell, so as to leave the branching processes clear and colourless. At other times the whole of the interior of the cells, even to the very extremity of the various processes, is more or less uniformly occupied by the diffused pigment, and then the irregular ramifications of the cells which anastomose are most plainly seen, and the whole appears black. In the former case the skin appears pale to the naked eye; in the latter, darker.

There is good reason, from observation and analogy, to believe that in other animals in which similar changes of colour are observed, and whose widely-varying hues are sometimes most beautiful and brilliant,—as in the chameleon, and some other lizards, some batrachia, many fishes, some cephalopoda,—these changes are connected with the arrangement of the pigment in their chromatophorous cells.

Now, it seems to be unquestionable that these changes are mainly determined by the operation of heat and light, although at present it is impracticable to estimate the relative influence of these forces. In the chameleon, for example, the most accurate observations shew that, contrary perhaps to popular opinion, the remarkable changes of colour which this animal exhibits are determined by the amount of heat and light which falls upon the surface. But, again, it seems to be beyond doubt that light alone will effect the change. Thus, apart from any appreciable variation of temperature, the skin of the common frog will exhibit various shades of colour according to the amount of light which it receives. When a frog passes from darkness into bright light, the comparatively dusky surface may be observed to become rapidly paler and clearer, and similar observations may be made on many fishes.

In this passing glance at the operation of the physical forces upon vital action, you see we are enabled to recognise the necessity of their presence, and some of the more striking effects of their influence. But the inquiry by no means ceases here. In truth, these preliminary facts conduct us only to the threshold of it. We may now go further; for a careful study of all the facts which we even at present possess, the evidence before us, will lead us to the conclusion that there is a definite ratio between the amount of force consumed and the results produced.

Although the data upon which it is founded are not, as yet, rigorously exact, we cannot resist the conclusion, that in plants and animals there is, within certain limits, a definite relation between the vital activity of each individual and the amount of force which it receives from external sources. Thus the most trustworthy observations tend to shew that every plant requires, to pass through its career, a definite amount of heat and light. An annual plant, for example, from the period of its germination to the close of its life, everywhere and under every circumstance, consumes the same total amount, whether it passes through its course most rapidly at the equator or more slowly in more temperate zones; its rate of growth being in a direct ratio to the amount which it receives in any given time. Or more particularly with regard to the operation of light on plants. There is satisfactory evidence for the conclusion, that the decomposition of carbonic acid, the appropriation of carbon, and the formation of chlorophyle are, other conditions being equal, in accordance with the amount of illumination a plant receives.

As with plants so with animals. Each individual in the course of its life appears to receive a definite amount of force from external sources, whether the intensity of its action be greater or less. The work done in the living body through the external forces is proportional to the amount transformed. For example, the experiments of Mr Higginbottom on tadpoles, previously referred to, shew that there is a definite relation between the temperature to which they are exposed, and the rate of their metamorphosis.

Now we call the force or forces by whose direct agency vital phenomena are produced the vital force or forces. By the term vital force, therefore, is understood a force acting only in living structures, and therefore so far peculiar.

In what relation, then, do the vital forces stand to the other forms of force? Is there any, and if so what, connexion between the physical and vital forces? True, we stand at present only on the threshold of this inquiry, but thus much may be safely said:—The farther we penetrate, the more we learn, the more are we led to believe that the phenomena of life are produced by the agency of the external forces, transformed by the organised structure through which they act. Thus, then, the vital or organic forces are correlated to the physical forces. We believe "that the same relation, in whatever way defined, exists among the several vital forces as among the physical; and that the vital and physical forces are themselves connected by a similar relationship."

Animals and plants have no power of creating matter. They can transform it only. Their relative power in this respect constitutes an important and interesting distinction between them. And as with matter is it not with force: not created by living beings, but by them transformed? It has been well pointed out that matter may be arranged in four planes. From below upwards—

An elementary plane.

A plane of chemical compounds.

A vegetable plane.

An animal plane.

This arrangement should be borne in mind in the consideration of the great question of conservation and transformation of force—of the relation of the vital to the external forces.

In nutrition, two series of changes are in progress—an ascending and descending one. With the discharge of function is necessarily associated the retrograde metamorphosis of tissue. Assimilation, on the contrary, implies the progressive metamorphosis of matter. Matter is raised to the level of living structure, and this involves the consumption of force; and from thence, as the necessary condition of the evolution of force, it descends until it reaches the level of the inorganic plane.

This may be roughly illustrated by the winding up of a clock, and the subsequent descent of the weight, or uncoiling of the spring.

In winding up a clock, the weight is raised by an external force—muscular exertion—through a certain arrangement of parts. Then as the weight descends, the clock goes; it discharges its function; it works. And the force by which the weight descends and produces motion of the hands, is exactly equivalent in its total amount to, although expended much more slowly than, the external force which we had supplied, and by which it was previously raised.

The weight is raised to a higher level, and this involves the consumption of external force, as in assimilation. Then it descends and evolves an equivalent amount of force in another form, and this is the discharge of function.

In assimilation, physical, including chemical, forces are consumed. But while, during life, vital forces are evolved by the retrograde metamorphosis of tissue, after death, physical and chemical forces only are evolved by the retrograde metamorphosis of tissue.

By way of further illustration, the correlation and mutual conversion of certain vital and physical forces may be more particularly indicated.

Nerve force may be excited through electricity. If an electric current pass along a short portion of a living motor nerve, contraction of the muscles supplied by it will be induced. By the same means the functions of other nerves may be excited. It is obvious that the effects are not produced by the immediate action of electricity, for they are manifested in the muscles, or in other organs which are not included in, but lie far beyond the current. Nor can such effects be produced through a dead nerve. Here, then, electricity, passing through nerve structure, becomes nerve force.

Again, the power of electric fishes is entirely dependent on the connexion of the peculiar apparatus which they possess with certain nerve centres, by means of nerve trunks. If these centres be destroyed, or the communication interrupted, the power is lost, while the effect of irritation of these centres transmitted to the apparatus excites electricity. Here, then, nerve force, passing through a special apparatus, appears as electricity.

So, too, heat may excite nerve force. If applied to a motor nerve in some part of its course, muscular contraction may be produced. It is now generally held that, in relation to temperature, the function of the nervous system is not a generative, but a controlling one. But nerve force may be conceived to be more immediately related to heat than this. As nerve force may be produced through heat, so it may be produced through chemical affinity, and so heat may perhaps arise directly out of nerve force. It may be conceived, on the one hand, that the union of carbon and hydrogen with oxygen, may, instead of producing heat, as out of the body, result in the production of nerve force in the body; and, on the other hand, considering how many points of resemblance there obviously are between nerve force and electricity, that nerve force, like electricity, may develop heat.* But granting all this, which at present is but a reasonable conception wanting proof, still chemical action nevertheless remains the source of animal heat, with this difference only, that instead of the whole of it resulting directly in the production of heat, more or less of it may pass through various intermediate forms of force; amongst others, of nerve force.

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* By carrying out this idea, it might be imagined that a closer relation, than has hitherto been shewn, prevails between nerve force and nutrition.

And while light falling upon the retina excites nerve force, some have already arrived at the conviction that the luminosity of certain worms and insects is produced, through a special apparatus, not out of chemical action, but, like the electricity of certain fishes, out of nerve force.

So, too, the reciprocal relation of nerve force and chemical affinity; of nerve force and motion, through the medium of muscle, might be indicated.

In the different movements which occur in living beings, examples are presented of the operation of various forces, all tending to a common result—motion. In osmose chemical force operates. "There is," says Graham, "a remarkably direct substitution of one of the great forces of nature by its equivalent in another force—the conversion, as it may be said, of chemical affinity into mechanical power." In elasticity an example is presented of a purely physical one. In muscular action vital force appears, but even here chemical force is involved. It is now universally admitted that the amount of muscular force employed is proportionate to the amount of muscular structure consumed, so that muscular action may be measured by the products of the metamorphosis of muscular tissue.

It is scarcely necessary to observe that the pre-existence of a living organism is necessary to the conversion of a physical into a vital force. But I cannot here forbear quoting some admirable remarks by Dr Carpenter, from whose labours I have drawn so largely in the previous pages. He says, "It is the *speciality* of the material substratum thus furnishing the medium or instrument of the metamorphosis which, in his opinion, establishes, and must ever maintain a well-marked boundary line between the physical and the vital forces. Starting with the abstract notion of force, as emanating at once from the

Divine Will, we might say that this force, operating through inorganic matter, manifests itself in electricity, magnetism, light, heat, chemical affinity, and mechanical motion; but that, when directed through organised structures, it effects the operations of growth, development, chemico-vital transformation, and the like; and is further metamorphosed, through the instrumentality of the structures thus generated, into nervous agency and muscular power. If we *only* knew of heat as it acts upon the organised creation, the peculiarities of its operation upon inorganic matters would seem as strange to the physiologist, as the effects here attributed to it may appear to those who are only accustomed to contemplate the physical phenomena to which it gives rise."

In conclusion, I would ask those, if any such there be, who refuse to accept this doctrine, to consider the alternative which they impose upon themselves. Is any difficulty removed, any obscurity cleared up, by the entirely gratuitous hypothesis that in all matter capable of organisation the vital forces as such exist in a dormant or latent condition? Or if the various forces manifested by the organism throughout life are not derived from without, what is their source? Are they from time to time created anew? Is such a doctrine credible by any well-informed mind? Or are they all at first stored up in the germ? Such an idea has been set forth. Can any one conceive it possible?

At all events, philosophy has happily done with the notion of a vital principle—of something unintelligible, which was, in the first place, assumed to exist, and then to whose powers was referred everything that was incomprehensible, that could not be satisfactorily explained by the operation of known causes. Nay, even actions that could be so explained were not. Men turned with horror from the simple idea that forces operating without could be found within the living body. There everything was mysterious, and being mysterious was at once referred to this vital principle.

Time forbids me to run the risk of wearying you in any attempt to trace the history of opinions on the nature of life, or it could be shewn, I think, that this dogma of a vital principle was no real advance upon, but far inferior to the ψυχὴ and *anima* of the ancients. The beautiful and ennobling idea of the classic poet lost all its charms in the rude hands of the modern philosopher. The "organic agent" was after all only a miserable vestige of the *spiritus intus.*[*]

But I need not at this time, and in this place, observe that the investigation of the phenomena of life has not been in any way assisted, that our knowledge of the vital processes has not been in the least measure advanced, by any such assumption. "Vital principle," "organic agent," and other like terms, when employed in physiology, are, even at the best, empirical ones, and equivalent to nothing more than the final letters of the alphabet in an algebraical formula; for they are, when used in their least objectionable sense, mere expressions of something unknown. But the assumption of such an agent or principle, how-

[*] Compare Prout, Gulstonian Lectures, Medical Gazette, vol. viii., with Virgil, Æneid, lib. vi.

ever designated, annihilating or suspending the operation of forces acting elsewhere, has not proved altogether harmless in its influence upon the progress of knowledge. By referring all vital actions to this obscure agency, while nothing was thereby explained, inquiry was to a great extent, and for a long while, checked. The final purpose was discerned, an efficient cause was forthwith assumed. Physiology fell idly back upon a vital principle.

Unfortunately much prejudice has been mixed up with these doctrines. To explain any of the phenomena of life by the operation of the physical forces, has been stigmatised as irreverent, as an attempt to defame the highest and noblest of the Creator's works. But is not such a charge as this altogether false and scandalous? The result being given—Life, it surely more exalts our feeble and imperfect conception of infinite intelligence and power to understand that the wonderful and mysterious phenonena of vitality have been evolved from the materials and forces around us, rather than by the introduction of distinct and peculiar agents. Many, dazzled by the idea that the nature of vital processes was exalted by thus associating them with some mysterious and peculiar principle, apart from and opposed to those agencies which act elsewhere, missed the simpler and grander conception that even in vital actions may be recognised the operation of forces, some of which, at least, are common to both kingdoms; while between these and others which appear to be peculiar to living structures, it is more than probable that a relation exists, like that which prevails between the physical forces.

Moreover, it may, in reply, be asked—Is there not much assumption involved in the confession that we are unable to construct the simplest form of living tissue? Men sometimes talk as if their powers were limited only by life. But can we construct a crystal any more than a nucleated cell? We may fulfil certain conditions under which, as we have learned from experience, crystals are formed, but what is our share in the act itself? In like manner we may take a seed or an egg and place it under circumstances in which it will develope. In either case we are acquainted with the necessary conditions, and we fulfil them. We can do no more. Truly it is our own fault if the fact be not thoroughly impressed on us that our power does not reach to the level of life.*

Let me, in conclusion, allude to one notable result, which may be deduced from all this; one fact which it will be well to bear in mind.

All vital action—active life depends essentially on these two conditions: a living organism possessed of properties never seen apart from life, and certain external agents operating through it.

Over the nature of the organism itself we have no direct power, but within certain limits we may control the operation of these external agents, and it is only, yet largely, through them that we can exercise any influence on the living body.

This fact it is which gives so much immediate interest to the investigation of the laws of their action. Here are, beyond all question, the great agents through which, when we have learnt how to handle them, we may act with the utmost advantage upon the organism.

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* For a lucid exposition of this subject, the reader may be referred to Mr Hinton's "Life in Nature"—a book which is throughout well worth reading.

The obvious purpose of, and the part played by food and air, as already illustrated, are to a certain extent appreciated. All understand that they are necessary to life, and most of us recognise more or less clearly their influence for good or for evil, according to the circumstances and conditions under which they are consumed.

But of the dynamical agents—the forces—we understand far less; in truth, as yet, but very little. Most of heat; less of light; scarcely anything of electricity. Still, now that a careful study of their action is following fast upon a recognition of their claims, we may trust soon to know much more, and to find that, in regard to the conditions of life and health, knowledge is power.

LECTURE IV.

Death; its Signification—General and Molecular Death—Modes of Dying—Signs of Death—Relation of Death to Life.

IV.

You will not, I am sure, think me wanting in what is due to the subject of this discourse, if I speak of it only from a scientific point of view. Even if there were no other reason why we should now confine our attention exclusively to the physiological aspect of death, the limits of a single lecture would bind us to that course. All other considerations must be, whether or not willingly, yet necessarily set aside.

I may say of death what I said of life : that no definition or description I could offer, would in any way present so vivid a picture of this great change, as the idea you already possess. We know that the cessation of this our life is death. Suffice it for the moment to say, "Death is that altered condition of an organic body in which it is no longer the subject of certain processes which constituted its life."

But death in the higher or more complete animals is not quite so simple a process as, to the first glance, it might appear to be. As death is the cessation of life, so it becomes more elaborate as we pass from the general to the special.

After the final cessation of certain functions on whose continuance life depends—after the last pulse has beat, and the last breath has been drawn—after a person has expired, and when to an ordinary looker-on all is still within; yet for a while life lingers here and there in various structures and organs. After what may be called the general death of the body, vital action still persists for a time in individual parts. Vital action may be clearly and unequivocally demonstrated to exist, for variable, even prolonged periods, in different structures. Thus we can understand how certain individual functions may be discharged for a while after the general death of the body. How for a time muscles may continue to contract, nerves to convey impressions, glands to secrete. How after the heart has ceased to beat, the blood may continue to move, for a time, through certain parts, so long as the changes which constitute nutrition still proceed.

Hence it becomes necessary to speak of general or systemic, or somatic death, and particular or special, or molecular death. And observe the kind of relation which exists between somatic and molecular death. Somatic death is sooner or later followed by molecular death, the interval varying in the several structures and organs according to external circumstances; but molecular death by no means necessarily involves general death. When any organ or structure is destroyed or removed, the effect produced will be in a direct ratio to the importance of its function in the economy.

Just as after the general death of the body, so will life endure for a while in certain parts after they are separated from the rest. And this duration of function—of vital action in isolated parts, appears to be, other conditions being equal, in an inverse ratio to the activity of the change which they undergo, or in other words to the energy with which they discharge their functions. Because the more active the changes in a structure, the more immediately dependent is it on those conditions, such as the supply of blood, which are now cut off.

The duration of vital action, or function, in individual structures or organs after general death, or their removal from the body, is, for many reasons, most conveniently studied in muscles. Their contractility is a well-marked vital property, and it can be easily excited by various means, but especially by galvanism.

The duration of muscular contractility, then, after death or isolation, can be readily studied. And let us observe, in the first place, that in the different members of the animal kingdom it is in an inverse ratio to the rate of change. Compare, for illustration, birds and mammalia with reptiles and fish, or insects with crustacea. Every one is more or less familiar with the obvious differences in these cases, and they strikingly set forth the relation which exists between the activity and duration of function in isolated parts.

According to the same law, the duration of function in isolated parts is influenced by their state, whether of repose or exercise. Other conditions being equal, a structure will retain its function longest, which under these circumstances exercises it the least.

So the duration of function in isolated muscles is influenced by their condition at the time of removal. If in a state of debility or exhaustion, either from defective nutrition or from excessive exercise, nothing but a feeble and transient manifestation of function remains; and this contrasts strongly with the vigour and endurance of fresh and healthy structures.

So from this we can understand the influence which the kind of general or somatic death has upon the duration of contractility in the muscular system; and why the contractility after death from lingering or convulsive diseases, which produce debility or exhaustion, is proportionably feeble and transient.

There can be no doubt that certain external conditions exercise a most important influence upon the duration of contractility after death or isolation. The chief of these appears to be the temperature to which muscles are exposed. Other conditions being equal, within certain limits, the duration of contractility appears to be inversely as the temperature. And there is good reason for believing that the great difference observed, in this respect, between the muscles of warm and cold blooded animals, is mainly due to the difference of temperature. For example, in some most interesting observations, Vulpian found that when the heart of a warm-blooded animal was after removal exposed to a low temperature, the period of its contractility was wonderfully prolonged. In one instance, some of the fibres were, by means of a lens, observed to contract slightly even after the expiration of ninety hours from the time of its removal from the body.

Now the facts which are thus set forth in muscles, may doubtless be extended to other structures. For instance, in relation to the last point—temperature—Brown-Sèquard's observations and experiments "clearly shew that the lower the temperature, the longer sensibility persists in parts deprived of circulation."

But farther than this. Although in man and the animals nearest to him the death of a part inevitably follows upon its isolation, yet this is by no means the case throughout the animal kingdom. In the simpler forms of life the several functions are less separated—there is less division of labour; consequently each part possesses to a corresponding extent the conditions which are essential to its life. In the simplest forms, where there is little, if any division of labour, any one portion may live apart from the rest; for all the functions of the animal, such as they are, may be said to be performed by every part of the organism. But as we pass on to the more complex animals—as the principle of division of labour is carried out—as various organs with special functions are evolved, so to a corresponding degree is their mutual dependence increased, inasmuch as while each contributes its share to the general result, each lacks that which the others supply. Therefore, the capability of living—of continuing life in isolated parts—is in an inverse ratio to the grade of development.

Thus, by division of the homogeneous substance of the amœba, the animal is merely multiplied—each fragment becomes forthwith a whole. So, though not quite so directly, with the common hydra. It may be divided and sub-divided, under favourable circumstances literally minced, and each part grows into a complete animal. Not only can each fragment maintain its life, but it can accomplish growth and development, the highest phases of it. Even if we pass to animals far beyond these, the same wonderful power is, though to a less degree, possessed. Many worms, when divided, have the power of reconstructing the whole from a part, and nothing can be more interesting and instructive than to trace the gradual manner in which this power dies out as we pass from the simplest to the most complex forms—from the general to the special. Nor can I, in relation to this, refrain from alluding to

Vulpian's remarkable observations. In describing these, he says—for he shall tell his own story —"Spallanzani has established that when one cuts off the tails of tadpoles, the tail is reproduced. This has been often confirmed. It occurs constantly, and may be repeated many times, as I have seen. But physiologists have not hitherto inquired what becomes of the tail which has been cut off. When the experiment is made upon tadpoles already well developed, the tail rapidly decomposes. It is very different, however, when the experiment is made upon very young embryos of frogs while they have yet their exterior branchiæ. The detached tail survives for some time, and exhibits interesting phenomena.

"The detached tails constantly live many days, accomplish movements when stimulated, often those of flexion and extension, as in swimming. But life is manifested by more singular and important phenomena. At the time when the experiment is made, the tail is formed of a median axis and two membraneous parts—one inferior, and one superior—the whole constituting the caudal fin. All the elements are, in these different parts, in the rough state—the epithelial cells, muscular fibres, nerve fibres, and blood vessels. Without entering now into detail, I can say that all these systems examined day by day perfect themselves more and more; they lose more and more their fœtal character; the elements multiply, and at the same time the vitelline granules which fill them tend completely to disappear. A cicatrix is formed at the place of section, a new part is added at this point to the tail, and this portion, which can constitute an eighth part of the total length of the tail, seems more young; it is more transparent; has not a median axis; the cells are filled with a great number of granules. . . . The tail flattens without enlarging. The vessels ramify. The stellate cells give rise to capillary blood vessels, and probably lymphatic. Pigmentary cutaneous cells appear. The muscular fibres which are separated by the intersections, and which form a great part of the axis, acquire a more defined character; the intersections are traversed by very apparent vessels, which give rise to a network of membraneous laminæ. In these vessels, lastly, one sees immovable blood globules, but they are modified during the time the tail survives. In one experiment, the tail survived from the 9th to the 27th of April 1858—about eighteen days. Then it was about to die, so I sacrificed it to examination. At the time of section, the blood globules were circular, almost colourless, and very granular. During the latter days of life, the granules had diminished in number, and had become extremely fine; many globules were oval, and lastly, they had acquired a decidedly yellow tint. These experiments do not succeed so well upon the embryo of tritons; the cohesion of their elements is weaker, and they rapidly crumble away. However, I have kept the tail of the larva of the triton, which has survived six days. It did not produce a true cicatrix; but drawings made each day shew considerable changes in the length, and otherwise, of the caudal portion of the segment. The elements of this part underwent sufficiently distinct modifications, but the duration of the experiment was not sufficiently long for the same amount of change as in the embryo of the frog.

"Thus, then, the tail of the embryo of the frog detached from the body may live during a score of days, and be the seat of the most incontestable vital phenomena. This cicatrization which is effected, this new part which is produced, are tendencies to restoration. Life, at this period, can segment itself, so to say, as in animals altogether inferior. But in proportion as the vital force operates, the elements with which it works multiply and perfect themselves: they attain soon a more elevated organization. The circulation then becomes an imperious necessity. whether for the transference of new material, or for removing material already used. Numerous and fine granules are deposited amongst the tissues. Life ceases."[*]

Those who still fondly cherish the notion of a vital principle must be shocked to find it in such reduced circumstances—compelled to reside for a while in the tail of a tadpole.

[*] Vulpian Brown-Sèquard's Journal, No. 4, p. 803.

In man the last faint, yet important, traces of this capacity are exhibited. Fingers, toes, noses, ears, when completely detached from the body, and reapplied at the divided surfaces, have reunited, and become restored; and this, in some cases, even when they have been separated for a considerable time. Now, during the interval of the separation of these parts, they must, of course, continue to live: if they perished one need not say that subsequent union would be impossible. For under no circumstances could a dead part be made to unite with a living one.

Upon this principle a portion of the living body may be transplanted from one part to another—in short, an operation akin to grafting in plants may be successfully performed. Hunter's celebrated experiment shews more than the simple fact. (See Lecture II., p. 54.)

Let us for a few moments glance at what, in one aspect at least, is a painful subject to contemplate—the modes of dying in different cases. These are various.

"A very little experience," says Dr Watson, "in the sick chamber, or in the wards of a hospital, will suffice to teach you that, although all men must die, all do not die in the same manner. In one instance, the thread of existence is suddenly snapped; the passage from life and apparent health, perhaps, to the condition of a corpse, is made in a moment: in another, the process of dissolution is slow and tedious, and we scarcely know the precise instant in which the solemn change is completed. One man retains possession of his intellect up to his latest breath: another lies unconscious and insensible to all outward impressions for hours or days before the struggle is over."

Death without any change in the organism—without any alteration of structure or composition, the body being, in this respect, the same as in life—is a mere assumption. It assumes that what we cannot demonstrate does not exist.

The proximate cause of death is the failure of some function, the due performance of which is necessary to life. When any organ or structure is damaged, the effect produced will be in a direct ratio to the importance of its function in the economy. Its loss may produce inconvenience merely, more or less severe and prolonged, either from its comparative insignificance, or because its function may be discharged vicariously by some other part, as, for example, in the case of a limb, or the spleen; or it may lead sooner or later to death, as life is more or less directly dependent on its function, as in the case of the stomach, certain nerve centres, lungs, or heart. The relation in which life stands to those functions on which it depends is extremely various. In some cases it is so remote that death follows their interruption only after a prolonged interval; in some, it is so close that death immediately succeeds their suspension.

Now, there are organs especially distinguished in this respect—the heart, the lungs, and certain nerve centres, commonly included in the term brain.* Why so? Life is directly dependent on the circulation of sufficiently pure oxygenated, that is, arterial, blood.

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* Hence Bichât spoke of death beginning at the heart, lungs and brain respectively. This arrangement has been modified and extended by Alison, Watson, and others.

Although not the sole, yet the heart is the principal agent in the circulation of the blood. In man and the higher animals, all the other forces concerned are quite subsidiary to the action of the heart, so that practically the circulation depends on the force of the heart's contraction, and fails when that gives way. Now, the heart may fail to circulate the blood from causes inherent in the organ itself. Its structure may become so altered that it is no longer capable of contracting with sufficient vigour; as, for example, when its muscular fibre degenerates into fat. In many cases of sudden death, and in others, too, in which death supervenes more gradually, the structure of the heart is found to be wonderfully changed. The fibre no longer presents the aspect of muscle, but consists only of granules and globules of oil; and the marvel of such cases as these is not why the heart ceased at length to beat, but how, under such change, it continued to work so long. Or, again, in consequence of this, or of some other change, the walls of the heart may be ruptured, the ventricles may be torn, and in these cases, in which the heart is literally broken, of course its function is forthwith arrested. These, then, are cases in which death begins immediately at the heart. Death by syncope or fainting.

But the action of the heart may be arrested by causes which operate through the nervous system. It is well known that the heart's action is not immediately dependent on the great nerve centres, for these may be cautiously removed, and yet its action will for a while continue. But that it may be powerfully, even fatally, influenced through them is familiar knowledge. It is quite true that the heart will leap from joy, or sink from fear, and emotions in still stronger degree may check its action to an extent sufficient to produce death. Thus, some have died from fright. So other impressions, acting through nerve centres, as violent blows on the epigastrium, or severe concussion of the brain, may arrest its action. In these cases, death begins at the heart, but not directly. The cause acts through certain nerve centres. Death from shock or by collapse.*

So may death begin immediately at the lungs. Venous is changed into arterial blood in the lungs in the presence of atmospheric air. If this change be prevented, the circulation through the lungs, and consequently elsewhere, is checked. Thus, death occurs in strangulation or suffocation. Atmospheric air, which is essential to the change on which the circulation depends, is shut out. If the occlusion be complete and sudden, the circulation is rapidly arrested; if it be but partial or gradual, for a while an impure blood languidly circulates, and the sequence is more prolonged and complicated; but in either case death begins at the lungs. Death by asphyxia, or, more properly, by apnœa.

But in the higher animals there is a special apparatus for the introduction and expulsion of air. Certain muscles, such as the diaphragm, are arranged to act in such a way as to enlarge the capacity of the thorax in inspiration; and this is immediately followed, when the muscles cease to act, by a recoil of the thoracic walls in expiration. Now, the action of the inspiratory muscles is thus brought about:—When venous blood flows to the lungs, the impression it produces there is conveyed through certain nerves to certain nerve centres, whence it is reflected to other nerves, which are distributed to the muscles in question; in obedience to which they contract and effect inspiration. Therefore the integrity of certain nerve centres is essential to the response of these muscles to the signal at the lungs. Now, when these centres are destroyed by injury, or damaged by disease, a great and necessary link in the chain is wanting. In vain the venous blood accumulating in the lungs produces a powerful impression there. It cannot be reflected to the muscles: it is lost. No air can enter: the blood stagnates: death follows. Thus people die with broken necks, and in most fatal cases of apoplexy. In these cases death begins at the lungs, but not directly. The cause acts through certain nerve centres. Death by coma.

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* Or by syncope. In this, as in the first case, it is commonly said that a person faints.

When the nerve centres are affected to a degree sufficient to impair their functions, but not damaged enough to destroy them, respiration may still be carried on, though with difficulty, and inadequately. The breathing is laboured; the blood is imperfectly purified; a dark stream circulates sluggishly, as the dusky surface shews. This morbidly impure blood, by the stronger impression it produces at the lungs, continues for a time to excite, to some extent, the failing nerve centres; but at length they cease to acknowledge the strongest impression, and the muscles no longer act. The seat of the mischief in these cases is beautifully shewn in the effects of what is termed artificial respiration. By certain movements of the arm, assisted by well-directed pressure upon the walls of the chest, its capacity may be alternately enlarged and diminished, so as to imitate, though but roughly and imperfectly, the effect of muscular action; and in this way life may be for some time prolonged, even when these nerve centres have been destroyed or removed. Should, however, their functions be paralysed by some temporary cause only, artificial respiration may be the precious means of carrying the all-important act of respiration over the terrible interval, until the function of the nerve centres is once again restored.

So then death may be produced through certain nerve centres in two ways. Either by the heart, as in sudden death from shock,* or by the lungs, as in slower death by coma.

Thus death begins at the heart or lungs either immediately, or through certain nerve centres.

But death may result either from a diminution of the quantity, or an alteration in the quality of the blood. When these causes produce death rapidly, it is obviously through the nerve centres. When they produce death slowly it is chiefly through them. And we can well understand why it is so. Because these organs, more than any others, are immediately dependent on a due supply of healthy blood.

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* Death from shock is probably death from temporary exhaustion of nerve force—the result of a violent, sudden, and excessive expenditure of it.

When hemorrhage—loss of blood—produces death, it acts through the nerve centres upon the heart and lungs, also, according to the rapidity with which it occurs and the suddenness of its effects. That sudden and profuse hemorrhage produces death through the great nerve centres is sufficiently obvious. The symptoms, the effects of position, and other circumstances, all point to this. When death is produced more slowly by this means, the case is not so simple and clear; yet still there is evidence of the same kind that it is produced chiefly through the same organs.

Hence also the immediate cause of death when the blood is poisoned. For the reason just given, the effects are more rapid and obvious upon the nerve centres, which consequently fail in that reflex action upon which the respiratory movements depend. Thus death is produced by coma in fatal cases of poisoning by alcohol, opium, and oftentimes in fevers.

Let us repeat, that the distinctive features—the symptoms during life and appearances afterwards—of each kind of death, or mode of dying, are most clearly marked in those instances in which the effects are most rapidly produced. Usually the more protracted cases are proportionately less simple ones; for during their progress one form of death is liable to be complicated by the intervention of causes which tend to produce death by a different mode. So we often witness in such cases—in fever, for instance—what may be called mixed forms of death. Still, for the most part, even in these complicated cases, the tendency to one particular mode of death is especially prominent.

If the various and manifold causes which, however remotely, tend to death, are carefully studied, it will be found that they at length bring life to an end through the interruption of the functions of one of these great organs.

And this directly leads me to notice what I believe to be a widely-spread error, the idea that under every circumstance the moment of death—of the great change, but not the greatest—that the moment of death is one of agony.

Now, those who have looked into this subject most closely agree in declaring that usually it is not so. In certain cases, the moment of dissolution may be one of extreme anguish; but these are exceptional. And indeed it follows from what has been already said—from the mode in which death supervenes—that the actual process of dissolution cannot be attended by pain or suffering. Some, we know, lie insensible for hours or days before death; and even those who retain in some degree the use of their faculties almost up to the very moment of death, cannot be in a condition to experience acute suffering. In order that the nerve centres, which are the seat of sensation, may discharge their functions, they must be properly supplied with healthy blood—no organs indeed depend so immediately on a due supply of pure blood as these—and when is this the case up to the moment of dissolution? In considering the modes of death, we have seen that it results either from deficiency or defect of the blood—because either too little is supplied, or that which circulates is too impure. As a consequence of this, the brain, of all the organs, will first fail in its function. We hear and read of persons retaining a clear and vigorous intellect up to the moment of departure ; but, in truth, such ideas and statements rest upon very shallow evidence. A few reasonable sentences uttered at intervals, or the repeated expression of some prevailing idea, can hardly go for so much.

But true is the instinct of love, which bids us fondly cling to parting words ; for we may reasonably believe that the ideas and sentiments which linger longest are, beyond others, vivid and intense. As the mind darkens, the thoughts that rise above the rest catch the last rays of intellectual light.

Then, again, many of the supposed signs of intense suffering are not really such. The cold dew upon the face and surface generally, the collapsed, and perhaps distorted features, the heaving, gasping or gurgling respiration, or it may be the convulsive agitation, are by no means necessarily the signs of pain and distress. Therefore, whatever may have been the amount of previous suffering, we may fairly assume that, except in extreme cases, the actual process of dying is not one of intense agony, or indeed, for the most part, even of pain. Again, we know that simple faintness may pass insensibly into death, and those who have been recovered from the verge of dissolution long after all consciousness and sensibility have ceased, have borne testimony to the same effect.

Sir B. Brodie says, speaking as Ergates, in his Psychological Inquiries, "Really, according to my observation, the mere act of dying is seldom, in any sense of the word, a very painful process."

It may be that in some cases when life is suddenly destroyed by injury or violence, the actual pangs of death are most acutely felt; and as a physican will, often at a glance, read the nature of the disease in the patient's face, so we observe varying expressions of countenance immediately after death. For example, on fields of battle the corpses of those who died of stabs are, we are told, easily distinguished by the countenance from those who fell by gunshot. The painful expression which remains on the faces of the former, contrasts with the serene composure on those of the latter. And indeed this holds good to a less degree in disease; and when we remember how calm and placid the aspect of death generally is,

> "Before decay's effacing fingers
> Have swept the lines where beauty lingers,"

we may well take comfort from

> "The mild angelic air,
> The rapture of repose that's there."

So with the dread of death. The king of terrors is not always most terrible when he approaches. I think no one who has often stood by the bedside of the dying can have failed to be struck by this fact—the comparative or complete absence of dismay as death draws near. Often, no doubt, the mind is otherwise too fully occupied, perhaps from intense bodily suffering; but even in the absence of this and of all other distracting influences, and with a clear conviction that the approaching change is near at hand, the mind is calm and collected, the thoughts serene, there is no quailing, no giving way. I appeal to those who are most familiar with the closing scenes of life, whether this be not so. Sir B. Brodie, with all his large experience, speaking in the character to which I have referred, says, "I have myself never known but two instances in which, in the act of dying, there were manifest indications of the fear of death." And Miss Nightingale, I think, has borne testimony to the same effect. I am sure that all who are accustomed to hospital practice must have been struck by the apparent apathy or indifference of patients as to the issue of the gravest injuries or diseases. The time of greatest mental distress is perhaps when the conviction first dawns upon us that we are about to die. The subsequent contemplation of approaching death seems to be far less terrible.

The dread of death is often absent, under other circumstances, in death from old age. I do not mean merely death in old people, but death from old age—and age, after all, is not to be measured only by the years attained, but rather by the amount of work done—death from a general and more or less equal wearing out of structures and organs. True, that this form of death seldom occurs; but something like it is sometimes seen. The forms or kinds of death to which I have hitherto alluded are what are termed premature or accidental deaths—death from the damage which some one or more parts have sustained, whose functions are essential to life, while the rest remain comparatively sound and healthy, or at all events sufficient for the purposes of life. All the organs are not worn out, but some one or more of them are damaged. This is the usual form of death. But it may occasionally occur that a person escapes or resists all the causes of disease, and lives on to extreme old age, his various organs gradually wearing out, and declining in their functions together, until at last life comes to a close, not from any special or local defect, but he falls asleep from a general deficiency of the vital powers. He dies of no disease, but of old age. This is rarer than at first sight it may appear to be, for even when great age has been attained we can usually detect some special defect as the prime cause of death.

Bichât, in his work on Life and Death, draws throughout the broadest distinction between organic and animal life; and in a chapter on the natural termination of the two lives, that is, death by old age, which, as he says, is rare, he describes how in the old man animal life ceases before organic life, how the senses severally fail, and the functions of the organs of relation gradually decline; and he passes his days concentrated upon himself, a stranger to all that surrounds him, deprived of desires, passions, and sensation, isolated in the midst of nature. Bichât explains this want of harmony in the decline of the two lives by the fact that, owing to our social relations, we use up or wear out our animal life much faster than the organic life. Man, in the midst of his fellows, exerts his animal functions far in excess of his organic. The brain and nervous system, for example, we know, are continually subjected to an undue amount of wear and tear. This idea is certainly an ingenious one; and he goes on to consider how this social influence upon the two lives or systems is, up to a certain point, advantageous for a man; how, by the failure of his senses, he is detached gradually from all that surrounds him, and so he suffers less cruelly at the moment when these ties are severed. He says, the idea of our supreme hour is painful, because all those functions cease which bring us into relation with that which surrounds us. It is the deprivation of these functions which spread fright and terror upon the border of our tomb. He assumes that a man would contemplate with indifference the approach of a death which deprived him only of his organic functions—of the circulation, digestion, and so forth—if the functions of relation were spared to him. So, he says, animal life comes to cease gradually; so each of the ties which enchain us to the pleasure of living are broken little by little, the pleasure escapes us unawares, and when at length a man has become oblivious of the cost, then death strikes him. It is thus, he adds, in the old age that comes with the successive and partial loss of his external functions, and the total loss of the sense of his existence. His end finds him like a vegetable, which fails in relative functions, having no consciousness of its life or knowledge of its death.

Is there not something inexpressibly gentle in this gradual severance of the ties between the conscious man and the world around him by the decay of the senses? As the cords that bind him to things present—and by which he was, at first, drawn thereto—are severed, his memory loosens its hold upon the past, and so the spirit is unshackled in its progress to the future.

I think some most interesting and significant observations might be made on the time of day or night at which death occurs. I believe a large number of observations would shew that it is more frequent at some hours than at others. The impression has been entertained by some that the greater number of deaths occur at or about daybreak. I do not know how this may be; but as lending some support to the idea I have expressed, I may say that during the months of last October, November, and December, (1862.) I collected from the medical and surgical wards of St Bartholomew's Hospital, without reference to person or disease or any other especial circumstance, one hundred and forty-four cases, in which the exact moment of dissolution was recorded. Taking mid-day and midnight as the extreme points, I found that between six in the morning and six in the evening, of the total number only sixty-one died ; whereas between six in the evening and six in the morning eighty-three died. Thus the ratio of the twelve hours, of which midnight is the centre, is to the twelve hours, of which mid-day is the centre, as four to three. Or, speaking broadly, we may say that one-fourth more died during the night than during the day.

Let us, for the few minutes that remain, review the signs of death, and note their value.

After death, the temperature of the body gradually falls ; it grows cold. The rate at which this occurs, however, is very variable, depending on—

External conditions ; such as the temperature of the surrounding medium.

internal conditions. The cause of the loss of heat is the cessation of those active changes which are characteristic of life. Changes occur after death, but more slowly.

Sometimes, however, the temperature is maintained or even raised for a while in a remarkable manner. Different observers have recorded the fact that in certain cases the heat of the body has been found not only to continue, but even to return at a considerable period after death has unequivocally taken place. There can be no doubt that this is due to chemical action. In such cases the combination of the oxygen with the elements of the body proceeds after death with extraordinary energy. And let it be here observed that, in order that a temperature after death may be sustained, nearly or quite equal to that which prevails during life, it is not necessary that an equal amount of heat be set free, for after death the means by which the temperature of the body is regulated during life are no longer in operation.

This maintenance or elevation of temperature after death may be produced artificially, as in animals poisoned by strychnia, in whom, for some minutes before death, violent spasms are produced. For examples :—

It having been ascertained that the temperature of a rabbit was 101° Fahr., ten minims of a solution of strychnia, containing one-twelfth of a grain, were administered. In three minutes decided spasms supervened, which continued for three minutes. During their action, the thermometer was introduced as before. It rose to 102°. Within a minute or two after death, it rose to 103°, and remained stationary at 103° for seven minutes after death. Then it gradually fell.

Again. The temperature of a dog was found to be 97°. Five minims of a solution of acetate of strychnia, containing one-fourth of a grain of strychnia, were then given. Spasms occurred in six minutes, and proved fatal in ten or twelve. During their continuance the temperature was 98°.

In these instances, no doubt, the active changes in the muscular tissue, which are, of course, associated with the violent action displayed, are sufficient, under the circumstances, for a time, actually to raise the temperature.

One of the surest signs of death belongs to the muscular system. It is the peculiar state into which the muscles pass at a certain period after death—a state of general contraction. All the muscles of the body—muscles of every kind—become firm and rigid, whereby the body is stiffened. This condition is known as *rigor mortis*, or the rigidity of death. It is very variable—

In the period after death at which it commences. It may set in immediately, without the lapse of any appreciable interval, or it may be delayed for eighteen, twenty-four, or more hours.

In its duration and intensity, which are generally directly proportionate. It may be most evanescent, or it may endure for one, two, or even three weeks.

The relation which exists between the period of its commencement and its term of duration has been well established. It may be stated as a rule that the longer its advent is delayed, the greater are its duration and intensity.

Although it is thus most variable, the probability is that it is never entirely absent. Hunter and others have indeed imagined that it does not occur in some forms of death, as in animals killed by lightning, or when death is preceded by excessive exhaustion. But in these and similar cases, it is more probable that it is not altogether absent; but being extremely slight and transient, has escaped observation. This will be better understood from a consideration of the circumstances which influence the supervention and duration of *rigor mortis*—its relation to muscular irritability, on the one hand, and to the decay which follows death, on the other.

It seems to be well established that, as Brown-Sèquard has expressed it, "The greater the degree of muscular irritability at the time of death, the later the cadaveric rigidity sets in, and the longer it lasts, and the later also putrefaction appears, and the slower it progresses."

Under whatever circumstances death occurs, this relation seems to hold good. For example, the following experiments, performed by Brown-Sèquard, are most instructive:—

"Five vigorous male adult Guinea-pigs were asphyxiated by the application of a ligature round the trachea, and four of them were galvanised immediately—the first with a very powerful electro-magnetic machine; the second with a weaker one; the third with a still weaker one; and the fourth by only a slight galvanic current; the fifth animal was not galvanised.

	Duration of Irritability.	Rigidity Completed.	Duration of Rigidity.
1st,....	4 mins.	7 mins.	15 mins.
2d,.....	40 „	60 „	Nearly 1200 „ (20 hours.)
3d,.....	90 „	120 „	Nearly 3600 „ (3 days.)
4th,...	330 „	420 „	Nearly 8600 „ (6 days.)
5th,...	500 „	600 „	Nearly 11,500 „ (8 days.)

"As regards putrefaction, it already appeared in the first animal during the first hour after death, and was much advanced the next day; its progress was slower in the four others, and necessarily slower in each as compared with the preceeding one in the series." And he adds, "Considering that the power of lightning may be vastly greater than that of our galvanic machines, we can easily understand that when lightning strikes a man or an animal in the proper place, it must produce a much greater effect than galvanism, reducing the duration of irritability to a fraction of a second, and that of cadaveric rigidity in a corresponding degree, so that no trace of it remains a few minutes after death, and in like manner hastening the access of the final process of putrefaction."

Again, the following tables shew the general result of experiments on one limb :—

ADULT RABBITS.

	Galvanised limb.	Limb not Galvanised.
Duration of Irritability, ...	7 to 20 mins.	120 to 400 mins.
Duration of Cadaveric Rigidity,	2 to 8 hours.	1 to 8 days.
Putrefaction much advanced,	Within a day.	Only after several days.

ADULT DOGS.

	Galvanised limb.	Limb not Galvanised.
Duration of Irritability,	12 to 25 mins.	140 to 550 mins.
Duration of Cadaveric Rigidity,	3 to 16 hours.	2 to 21 days.
Putrefaction much advanced,	Within 30 hours.	Only after several days."*

Thus, by means of galvanism we can regulate muscular exhaustion with great accuracy, and so determine the period of access, the duration and intensity of *rigor mortis.*

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* Croonian Lecture. Proceedings of the Royal Society, vol. xi., No. 44.

Again the contrast is great between men dying in a state of robust health, and others after prolonged and exhausting diseases, or from diseases such as cholera or tetanus, or from poisons producing convulsions. This is clearly illustrated by the following experiment of Brown-Sèquard:—

"Three dogs, as much alike as possible, and apparently in perfect health, were poisoned by the acetate of strychnine. One of them had a dose of two grains, another half-a-grain, and the third one-fourth of a grain. The first dog died at once, the second after twelve minutes, during seven of which it had convulsions, the third after twenty-one minutes, during eleven of which it had convulsions.

	Duration of Muscular Irritability.	Duration of Cadaveric Rigidity.	Putrefaction.
1st dog,	8 hours.	19 or 20 days.	Slow.
2d dog,	$2\frac{1}{2}$ "	5 days.	Rapid.
3d dog,	$\frac{1}{2}$ "	Less than a day.	Very rapid.

He adds, "In rabbits, Guinea-pigs, cats and birds, as well as in dogs, I have ascertained that when they are killed by poisons causing convulsions, the more violent and the more frequent the convulsions are, the sooner cadaveric rigidity sets in, and the less is the time it lasts; the sooner also does putrefaction appear, and the quicker is its progress."

So again the contrast is strikingly shewn between healthy animals, which for hours or days before death have been allowed to remain undisturbed, or not subjected to great muscular exertion, and others which have been previously overdriven or hunted to death. The practical application of this fact to the slaughtering of cattle for food is obvious. The same difference has been observed in the case of men. Thus the bodies of soldiers who have been killed on the battle-field late in the day, that is, after prolonged fatigue, have become rigid before the bodies of those who fell earlier, while fresh, in the fight.

In relation to this subject I must refer to a curious but well-authenticated fact. On the battle-field, towards the close of, or immediately after the fight, the following startling spectacle has been occasionally witnessed—A soldier has appeared to be resting in some strange position, perhaps kneeling with his musket to his shoulder as if about to fire, but on closer inspection he has been found to be dead; a rigid corpse with the semblance of energetic life. Such an instance which occurred at the battle of the Alma was recorded,* and I have heard of others somewhat similar which were met with on the field of Solferino. Nor are these cases unparalleled. Similar instances occurring elsewhere have been from time to time recorded.

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* The following is an extract from a letter of the special correspondent of the *Times* newspaper, as it appeared in that journal, on Wednesday, October 11, 1854. Mr Wm. H. Russell is describing the scene after the battle of the Alma:—

"The attitudes of some of the dead were awful. One man might be seen resting on one knee, with the arms extended in the form of taking aim, the brow compressed, the lips clenched—the very expression of firing at an enemy stamped on the face, and fixed there by death; a ball had struck this man in the neck. Physiologists or anatomists must settle the rest. Another was lying on his back, with the same expression, and his arms raised in a similar attitude, the minié musket still grasped in his hands, undischarged. Another lay in a perfect arch, his head resting on one part of the ground and his feet on the other, but the back raised high above it. . . . Some of the dead lay with a calm, placid smile on the face, as though they were in some delicious dream."

Brown-Sèquard refers to a case, in Taylor's Medical Jurisprudence, of a man who kept his arms extended for a while to avoid being drowned. The arms after death were found rigid in the position they had before.

Now the explanation which has been given of these cases is that, in consequence of the previous excessive exertion to which the muscular system had been subjected, rigidity came on at once, so immediately that the muscles became forthwith fixed in the position in which they were at the instant of death.

I venture to doubt the validity of this explanation, at all events for all these cases.

In the first place, there is, as we have seen, such a relation between the period after death at which *rigor mortis* sets in, and the degree to which it proceeds, that when it immediately supervenes—as it must in these cases for the explanation to hold good—it is most feeble and transient. In such cases, therefore, I doubt whether it could prove sufficient to maintain the position for any length of time.

But, again, there are cases recorded presenting features similar to these, which have occurred under circumstances in which there could scarcely have been any corresponding degree of previous muscular exhaustion. These have received a very different explanation.

"M. Marc relates the case of a gentleman who went to a theatre, apparently in good health, and after the representation was over, was found by his friends sitting in the front of the box, with his head resting upon his hands, and his elbows on the ledge. He had died of apoplexy, and been retained in that position by the tonic spasm of his muscles. This contraction is unquestionably vital, but it ceases after a few hours, and," Dr Symonds adds, "the flexibility is then succeeded by true cadaveric rigidity."

"A case occurred in France some years ago. The body of a man named Courbon was found in a ditch, with the trunk and limbs in such a relative position as could only have been maintained by the stiffness of the articulations. This stiffness, moreover, must have come on at the very time when the body took the said position ; unless it could be imagined that the body had been supported by the alleged murderers until the joints were locked by cadaveric stiffness, a supposition infinitely too improbable to be entertained for an instant. But by regarding the rigidity as of a spasmodic nature (resulting from apoplexy, of which there were sufficient proofs in the necroscopy) the difficulties of the case were altogether removed."*

It appears to me, therefore, that some other or farther explanation of these facts is required. May it not be that in these cases there is, as in those just quoted, from some injury to some portion of the nervous system at the moment of death, severe tetanic spasm produced, which, after a while, in consequence of extreme exhaustion, passes insensibly into *rigor mortis?*

It has been observed, that in certain cases some of the muscles pass into a state of cadaveric rigidity before general death has supervened. "In a man," says Brown-Sèquard, "who died at the Hôpital du Gros-Caillou at Paris, in the summer of 1849, cadaveric rigidity became evident within three minutes after the last breathing, and while the heart was still beating twenty times in a minute, *i.e.*, while the man was still alive, if life is considered to persist so long as the heart beats. These beatings ceased only three minutes and a half after cadaveric rigidity had shewn itself everywhere. A quarter of an hour afterwards there was no trace of cadaveric rigidity; and in less than an hour after death signs of putrefaction had appeared in the limbs. This man died of exhaustion after a prolonged typhoid fever."

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* These cases are quoted from *Annales d'Hygiène*, &c., tom. vii., by Dr Symonds, in his article *Death*, in the Cyclopædia of Anatomy and Physiology.

Kussmaul and Tenner state, in their monograph on epileptiform convulsions from hemorrhage, that "It is sometimes observed, after the arteries of the neck have been tied, that the muscles of the trunk perish, and take on the *rigor mortis* before the action of the left heart is extinct. Hence the left heart is not always the *primum moriens* among the muscular organs." This rapid supervention of *rigor mortis* is doubtless due to exhaustion produced by the previous convulsions of these muscles which follow the operation.

It deserves to be noticed that Brown-Sèquard has restored the contractility of muscles, and at the same time completely removed the rigidity with which they had become affected in the bodies both of man and animals some time after death, by injecting into the vessels arterial blood deprived of its fibrine, or defibrinated venous blood previously reddened by exposure to the air. The arterial blood employed assumed, during its passage through the limb, the venous character, and issued of a dark colour. This restoration of contractility was by no means imperfect or transient; in one instance it continued for two hours.

As a rule, after death the blood coagulates. This change, however, is much influenced by the form of death, the previous condition of the individual, and other circumstances.

This event, like the last, has been supposed by Hunter and others not to occur after certain kinds of death; as, for example, in those killed by lightning, and in animals hunted to death. Others, however, as Gulliver, have, by shewing that in many of these cases the blood does coagulate, rendered it doubtful whether it is entirely absent in any of them.

Again, Gulliver relates cases in which the blood did not coagulate after death from carbonic acid.

Certain it is, that after some kinds of death and certain diseases the coagulation of the blood is but partial and imperfect. I, in common with others, have observed this after death in some cases of *delirium tremens;* and after sudden or rapid death from some active poisons a large proportion of the blood will remain fluid, while only here and there dark and soft and very imperfectly-formed clots will be found.

There is certainly in the great majority of cases a correspondence between the coagulation of the blood and muscular rigidity in the extent to which they occur, a correspondence which further appears in the relation which the period of advent of each bears to the degree to which it proceeds; a correspondence, however, which, it must be confessed, appears at present not to be so invariable as to support the doctrine that they are related as cause and effect. Still when the relation which muscular fibre bears to the fibrine of the blood is considered, this marked correspondence which unquestionably obtains between the coagulation of the one, and the rigidity of the other is, to say the least, significant.

Lastly, sooner or later after death decomposition prevails. The body decays. This, too, in its onset and progress is most variable, being influenced—

By the nature of the various tissues. The difference is most marked between hard and soft parts; some disappearing rapidly after death, while the bones endure, comparatively little changed, for ages.

By external conditions; such as the presence of air and water, and the temperature.

Horrible instances of decomposition, like that which prevails after death, have been witnessed during life. Dr Carpenter says [*] he "has been informed by Dr Daniell that it is not at all uncommon, in negroes who are in the last stage of the adynamic fevers of the African coast, for death and decomposition to extend gradually upwards from the extremities to the trunk, so that the former may be in a state of absolute putrescence before the respiration and circulation have been brought to a stand; and he learns from Professor Jackson of Philadelphia that he has more than once witnessed the same occurrence."

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[*] Principles of Human Physiology, 1855, p. 923, note.

Decomposition, indeed, is not peculiar to death; but now there is no renewal, no longer any compensation for the loss, while the products are not excreted as fast as they are formed, so the slower changes after death are more obvious than the active changes during life. Moreover, the forces thence evolved are only those common to inanimate matter. Thus, the decay which follows upon death is plain to all, and everywhere recognised as the clearest proof of it.

After death, then, decomposition—decay. The body disappears. During life also, active, ceaseless decomposition. Contemplate for a moment the great changes through which we pass, recall for an instant the metamorphoses we undergo; how at different ages we, in structure, in body, differ from ourselves; how our persons are transformed though our individuality is preserved. Nay, look at the evanescent character of all living structure—how rapidly it is changed. Every particle or atom of which our bodies are composed has but a transient residence there. It is not long a part of us. Whence has it come? Whither is it going? We know that the elements of which we are composed are indestructible. Whither then do the particles that for a time construct our bodies go? Into other forms. Even as they came from without—from other forms, mineral, vegetable, or animal, even, though indirectly, from other men—so do they return whence they came to enter into other forms again. Thus are the elements ever revolving in a cycle through the kingdoms of nature; from the inorganic to the vegetable, from the vegetable to the animal, from the animal back to the inorganic kingdom. See, then, we can claim no atom of our bodies as particularly our own, or in any sense peculiar to us. Each is but borrowed for a time to be rapidly restored.

And of our forces. All that we know of force tells us that it cannot, any more than matter, be annihilated. When either disappears it assumes other forms. Some of the forces operating within us we know are common to the living body and to inanimate matter. We recognise the play of chemical and physical forces in the living body. And those whose operation we detect only in living structure, in what relation do they stand to the rest? If the vital and other forces are not correlative and mutually convertible, what becomes of these vital forces after death? Are they annihilated? Can we, in the face of all analogy, believe this? Is it reasonable? If not, do they not pass into other forms of force? Do they not then arise from them?

Yet while science demonstrates all this change—this transformation, this death, as the very condition of life—we need no teaching to tell us that we ourselves, in spirit, are not thus changed. There is nothing of which we are more sure, or so conscious as of this. See, then, how the beams of science lighten up our faith. Well may that survive death which survives this our life. For what material change is there in death more than in life?

> "There is no death! what seems so is transition;
> This life of mortal breath
> Is but a suburb of the life Elysian,
> Whose portal we call death."

THE END.

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